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## ACCESSION NUMBER RANGES

Accession numbers cited in this Supplement fall within the following ranges.

STAR (N-10000 Series)    N90-15041 — N90-16706

IAA (A-10000 Series)    A90-20013 — A90-23750

# AERONAUTICAL ENGINEERING

## A CONTINUING BIBLIOGRAPHY WITH INDEXES

(Supplement 252)

A selection of annotated references to unclassified reports and journal articles that were introduced into the NASA scientific and technical information system and announced in April 1990 in

- *Scientific and Technical Aerospace Reports (STAR)*
- *International Aerospace Abstracts (IAA).*



National Aeronautics and Space Administration  
Office of Management  
Scientific and Technical Information Division  
Washington, DC

1990

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# INTRODUCTION

This issue of *Aeronautical Engineering -- A Continuing Bibliography* (NASA SP-7037) lists 425 reports, journal articles and other documents originally announced in April 1990 in *Scientific and Technical Aerospace Reports (STAR)* or in *International Aerospace Abstracts (IAA)*.

The coverage includes documents on the engineering and theoretical aspects of design, construction, evaluation, testing, operation, and performance of aircraft (including aircraft engines) and associated components, equipment, and systems. It also includes research and development in aerodynamics, aeronautics, and ground support equipment for aeronautical vehicles.

Each entry in the bibliography consists of a standard bibliographic citation accompanied in most cases by an abstract. The listing of the entries is arranged by the first nine *STAR* specific categories and the remaining *STAR* major categories. This arrangement offers the user the most advantageous breakdown for individual objectives. The citations include the original accession numbers from the respective announcement journals. The *IAA* items will precede the *STAR* items within each category.

Seven indexes -- subject, personal author, corporate source, foreign technology, contract number, report number, and accession number -- are included.

An annual cumulative index will be published.

Information on the availability of cited publications including addresses of organizations and NTIS price schedules is located at the back of this bibliography.

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# TYPICAL REPORT CITATION AND ABSTRACT

NASA SPONSORED  
 ↓  
 ON MICROFICHE

ACCESSION NUMBER → **N90-10834\*** # Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics. ← CORPORATE SOURCE

TITLE → **AN EXPERIMENTAL INVESTIGATION OF THE AERODYNAMIC CHARACTERISTICS OF SLANTED BASE OGIVE CYLINDERS USING MAGNETIC SUSPENSION TECHNOLOGY**

AUTHORS → **CHARLES W. ALCORN and COLIN BRITCHER** Nov. 1988 ← PUBLICATION DATE  
 90 p

CONTRACT NUMBER → (Contract NAG1-716) ← AVAILABILITY SOURCE

REPORT NUMBERS → (NASA-CR-181708; NAS 1.26:181708) Avail: NTIS HC A05/MF A01 ← PRICE CODE

COSATI CODE → CSCL 01/1

An experimental investigation is reported on slanted base ogive cylinders at zero incidence. The Mach number range is 0.05 to 0.3. All flow disturbances associated with wind tunnel supports are eliminated in this investigation by magnetically suspending the wind tunnel models. The sudden and drastic changes in the lift, pitching moment, and drag for a slight change in base slant angle are reported. Flow visualization with liquid crystals and oil is used to observe base flow patterns, which are responsible for the sudden changes in aerodynamic characteristics. Hysteretic effects in base flow pattern changes are present in this investigation and are reported. The effect of a wire support attachment on the 0 deg slanted base model is studied. Computational drag and transition location results using VSAERO and SANDRAG are presented and compared with experimental results. Base pressure measurements over the slanted bases are made with an onboard pressure transducer using remote data telemetry. Author

# TYPICAL JOURNAL ARTICLE CITATION AND ABSTRACT

NASA SPONSORED  
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 ON MICROFICHE

ACCESSION NUMBER → **A90-13017\*** # Texas A&M Univ., College Station. ← CORPORATE SOURCE

TITLE → **IN-FLIGHT BOUNDARY-LAYER TRANSITION MEASUREMENTS ON A SWEEP WING**

AUTHORS → **ANWAR AHMED (Texas A & M University, College Station), WILLIAM H. WENTZ (Wichita State University, KS), and R. NYENHUIS (Cessna Aircraft Co., Wichita, KS)** ← AUTHORS' AFFILIATION  
 Journal of Aircraft ← JOURNAL TITLE  
 (ISSN 0021-8669), vol. 26, Nov. 1989, p. 979-985. refs.

CONTRACT NUMBER → (Contract NAG1-104) Copyright

Flight tests were conducted at three different altitudes to detect transition on a smoothed test region of a swept-wing business jet wing using surface hot-film sensors and sublimating chemicals. Strong influence of sweep angle on transition location was observed when the aircraft was flown at some sideslip conditions to simulate changes in effective wing sweep angle. No effects of engine noise on transition were measured when different engine power settings were used. Flight instrumentation and ground data analysis techniques are described. Correlation was obtained between the hot-film sensor signals and sublimating chemicals for transition detection. Crossflow vortices were observed for one flight condition. Results of analyzed data for various flight-test conditions are presented. Author

# AERONAUTICAL ENGINEERING

*A Continuing Bibliography (Suppl. 252)*

MAY 1990

01

## AERONAUTICS (GENERAL)

**A90-20576**

**AIAA LIGHTER-THAN-AIR SYSTEMS TECHNOLOGY  
CONFERENCE, 8TH, JACKSONVILLE, FL, OCT. 5-7, 1989,  
TECHNICAL PAPERS**

Conference sponsored by AIAA. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, 85 p. For individual items see A90-20577 to A90-20587.

Copyright

The present conference on LTA vehicle design concepts, applications, and analytical tools discusses the use of an airship as an oceanographic research platform, an airborne early warning (AEW) metalclad airship, the 'Heliship' hybrid airship concept, offensive uses of naval airships, and future LTA systems for naval missions. Also discussed are an airship damage strategy, an analytical technique for airship ditching behavior, the application of modern technologies to airship design, a control-configured airship, the parametric sizing of naval airships, the prediction of aerostat and airship mooring mast loads by nonlinear dynamic simulation, a variable-geometry airship concept, and the definition of airship system requirements for AEW platform use. O.C.

**A90-20606**

**REPAIR OF COMPOSITE AIRCRAFT PARTS - AN  
OPERATOR'S VIEWPOINT**

K. B. ARMSTRONG (British Airways, Hounslow, England) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100), vol. 203, no. G2, 1989, p. 105-112. refs

Copyright

This paper discusses the problems of repair experienced by aircraft operators and some actual repairs are mentioned. The use of cold-setting adhesives is compared with the hot-setting pre-pregs recommended by the manufacturers. A need is then shown for more mechanical and physical property data on both the original pre-preg resins and the cold-setting resins that may be used for repair when the provision of hot-curing is difficult.

Author

**A90-21702**

**THE U.S. AIRLINE INDUSTRY - COPING WITH AN AGING  
FLEET**

Aerospace Engineering (ISSN 0736-2536), vol. 10, Jan. 1990, p. 13-17.

Copyright

The average active service life of U.S. commercial aircraft has increased from 8 years in 1980 to 12 years in 1989. Airliner design goals strive for an 'economic' service life of 20 years, in conjunction with an about 40-year useful life if the aircraft is adequately maintained; the issue currently being debated by industrial and regulatory authorities is whether the fail-safe design practices employed 20-30 years ago remain adequate, as the aircraft in question begin to approach or exceed their economic life limit.

The incomplete removal of corrosion damage during maintenance and repair is noted to be a frequently encountered problem.

O.C.

**A90-21714**

**EUROFIGHTER FIGHTS BACK**

GUY NORRIS Flight International (ISSN 0015-3710), vol. 137, Jan. 3, 1990, p. 24-27.

Copyright

The European Fighter Aircraft (EFA) program is examined. The current stage of development and future consideration for the EFA are discussed. The contributions by West Germany, Italy, Spain and the UK to the EFA program, and the awarding of contracts for the development of aircraft systems are described. Applications for the EFA and economic benefits provided by the program are also discussed. I.F.

**A90-21715**

**MATERIAL PROGRESS**

GRAHAM WARWICK Flight International (ISSN 0015-3710), vol. 137, Jan. 3, 1990, p. 30-33.

Copyright

The use of composites in aircraft design is analyzed in terms of cost. The fabrication of resin-matrix composites is more costly than for Al alloys. Fabrication processes that reduce the cost of composites are described. Particular attention is given to thermoplastic forming, robotic drilling, and resin transfer molding. Specific uses for composites in aircraft design are discussed.

I.F.

**A90-22649**

**THE IMPACT OF COMPOSITES ON THE AEROSPACE  
INDUSTRY [IMPACTO DE LOS COMPOSITES EN LA  
INDUSTRIA AEROESPACIAL]**

ANTONIO MARTIN-CARRILLO DOMINGUEZ (Construcciones Aeronauticas, S.A., Madrid, Spain) Ingenieria Aeronautica y Astronautica (ISSN 0020-1006), Dec. 1989, p. 11-16. In Spanish. refs

Copyright

An account is given of the development status and characteristic applications of composites in aerospace vehicles, with attention to the widely employed carbon (or graphite) fiber-reinforced epoxy laminates. The prospects for future use of composites is anticipated in such projects as the All-Composite Airframe Program, which has resulted in the construction of a helicopter whose primary and secondary structures are fabricated from kevlar-, kevlar/graphite hybrid-, and graphite-reinforced polymer matrices in both sandwich and laminate forms. The substantial percentage of composites in the structures of the F-18 and next-generation EFA fighters is also noted. O.C.

**A90-22696#**

**EUROFAR - EUROPEAN PROJECT FOR A COMMERCIAL  
VERTICAL-TAKEOFF AIRCRAFT [EUROFAR -  
EUROPAEISCHES PROJEKT FUER EIN SENKRECHT  
STARTENDES VERKEHRSFLUGZEUG]**

WOLFGANG MUGGLI, R. D. VON RETH, and HELMUT HUBER (MBB GmbH, Ottobrunn, Federal Republic of Germany) DGLR, Jahrestagung, Hamburg, Federal Republic of Germany, Oct. 2-4,

## 01 AERONAUTICS (GENERAL)

1989, Paper. 10 p. In German.  
(MBB-UD-553/89)

The EUROFAR project for a commercial aircraft capable of vertical takeoff is discussed. The infrastructure requirements of the project and the city-to-city, offshore, and specialized services that it will offer are examined. The market for the aircraft is discussed, and a technical description is given of the EUROFAR baseline vehicle. The aircraft's operational characteristics are examined. C.D.

**A90-22698#**

### **SCENARIO 2000 [SZENARIO 2000]**

VOLKER VON TEIN (MBB GmbH, Ottobrunn, Federal Republic of Germany) Internationales Hubschrauberforum, Bueckeburg, Federal Republic of Germany, May 9, 10, 1988, Paper. 16 p. In German.  
(MBB-UD-560/89)

Near-term trends in some aircraft technologies are discussed. Market-driven trends and trends dependent on VTOL technology are addressed. The environmental impact of the VTOL design is considered, and the needs for balanced design are discussed. Technically sensible VTOL concepts are reviewed, and the evolution of rotating wing technology and the step function is examined. Coming military and civil use of rotating wing aircraft are considered. C.D.

**A90-23416**

### **DESIGN OF COMPUTER-AIDED TESTING SYSTEMS FOR AVIATION EQUIPMENT. I [PROEKTIROVANIE AVTOMATIZIROVANNYKH SISTEM ISPYTANII AVIATSIONNOI TEKHNIKI. I]**

IU. V. KOZHEVNIKOV and A. KH. KHAIRULLIN AviatSIONnaia Tekhnika (ISSN 0579-2975), no. 4, 1989, p. 64-67. In Russian.  
Copyright

The objectives, principles, and techniques of the design of computer-controlled testing systems for aviation equipment are briefly reviewed. The life cycle of flight vehicles and a typical test cycle are discussed. A unified representation is proposed for the knowledge base of a computer-aided test system. V.L.

**A90-23662**

### **FROM THE DC-3 TO HYPERSONIC FLIGHT - ICAO IN A CHANGING ENVIRONMENT**

EUGENE SOCHOR Journal of Air Law and Commerce (ISSN 0021-8642), vol. 55, Winter 1989, p. 407-440. refs  
Copyright

The International Civil Aviation Organization (ICAO) sets standards but cannot enforce them, and formulates solutions to emerging problems but cannot impose them. Because states treat the field of economics as their sole prerogative, the ICAO has never been allowed to exercise authority over economic matters. Nothing in the Chicago Convention, however, prevents the ICAO from assuming such a responsibility; based on a broad interpretation of its objectives, the ICAO cannot fulfil its mission without addressing the economic and regulatory issues standing in the way of an efficient and economical use of air transport. O.C.

**A90-23680**

### **THE ROBOTIC CANOPY POLISHING SYSTEM**

STANLEY D. YOUNG and DOUGLAS L. MICHALSKY (Southwest Research Institute, San Antonio, TX) Society of Manufacturing Engineers, Robots in Aerospace Manufacturing Conference, Irvine, CA, Feb. 20-23, 1989. 14 p.  
(SME PAPER MS89-134) Copyright

The Robotic Canopy Polishing System (RCPS) developed for USAF use employs two robots for the simultaneous polishing of aircraft canopies in conjunction with a third robotic unit which monitors the process by means of machine-vision techniques; this polishing improves both the optical characteristics of scratched and pitted canopies and their structural integrity. The results of RCPS operations have been found to be cost-effective, with good polishing repeatability. O.C.

**A90-23683**

### **DESIGN FOR ASSEMBLY OF AEROSPACE STRUCTURES - A QUALITATIVE, INTERACTIVE APPROACH**

GARY A. GABRIELE (Rensselaer Polytechnic Institute, Troy, NY) and JAMES P. BAUM Society of Manufacturing Engineers, Robots in Aerospace Manufacturing Conference, Irvine, CA, Feb. 20-23, 1989. 16 p.

(SME PAPER MS89-158) Copyright

A qualitative, design-for-assembly (DFA) methodology specifically oriented to the requirements of aerospace structures has been developed and implemented on a PC with the HYPERTALK programming language. The strategy employed was intended both to teach design personnel the concepts of the DFA system and to improve an actual design project. Attention is given to the DFA system's illustrative application to the design of a fuselage structure panel; several features whose assemblability could be improved were identified and modified accordingly. O.C.

**N90-15041#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Flight Mechanics Panel.

### **FLIGHT IN ADVERSE ENVIRONMENTAL CONDITIONS**

Sep. 1989 379 p In ENGLISH and FRENCH Symposium held in Gol, Norway, 8-11 May 1989

(AGARD-CP-470; ISBN-92-835-0527-1) Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Four aspects of adverse environmental conditions of interest to the flight mechanics specialist were addressed: atmospheric disturbances, reduced visibility, icing, and electromagnetic disturbances. All four of these can seriously affect flight safety, comfort, and operational capability. The topic was considered to be particularly relevant to the needs of the military community which is putting increased emphasis on the ability of today's and tomorrow's aircraft to fly safely and effectively in the types of adverse conditions.

## 02

## AERODYNAMICS

Includes aerodynamics of bodies, combinations, wings, rotors, and control surfaces; and internal flow in ducts and turbomachinery.

**A90-20432**

### **VIBRATION OF A WING OF NONZERO THICKNESS IN SUPERSONIC FLOW [KOLEBANIIA KRYLA S NENULEVOI TOLSHCHINOI V SVERKHZVUKOVOM POTOKE]**

B. A. ERSHOV IN: Stability and vibrations of mechanical systems. Leningrad, Izdatel'stvo Leningradskogo Universiteta, 1988, p. 87-90. In Russian.

Copyright

The coupled vibrations of an elastic infinite-span wing of nonzero thickness in supersonic flow are investigated analytically. The integro-differential equation of vibrations is compared with the corresponding equation for a thin wing. It is shown that the wing thickness characteristics are included in the airfoil vibration equation only through cylindrical stiffness and linear mass. V.L.

**A90-20442**

### **A STUDY OF THE STABILITY OF A WING AILERON IN SUPERSONIC FLOW [ISSLEDOVANIE USTOICHIVOSTI ELERONA KRYLA V SVERKHZVUKOVOM POTOKE]**

I. G. LUKINYKH IN: Stability and vibrations of mechanical systems. Leningrad, Izdatel'stvo Leningradskogo Universiteta, 1988, p. 178-180. In Russian.

Copyright

The paper is concerned with the problem of determining the dynamic stability of the elastic aileron of an infinite-span wing in



supersonic flow of a gas. The problem is formulated using a coupled system of moving coordinates. The resulting equation is solved numerically using the Bubnov-Galerkin method. V.L.

**A90-20501**

**NONLINEAR STABILITY OF SUBSONIC MIXING LAYERS WITH SYMMETRIC TEMPERATURE VARIATIONS**

V. D. DJORDJEVIC (Beograd, Univerzitet, Belgrade, Yugoslavia) and L. G. REDEKOPP (Southern California, University, Los Angeles, CA) Royal Society (London), Proceedings, Series A - Mathematical and Physical Sciences (ISSN 0080-4630), vol. 426, no. 1871, Dec. 8, 1989, p. 287-330. refs

(Contract F49620-85-C-0080; N00014-86-K-0679)

Copyright

The nonlinear evolution of stability waves in mixing layers of a perfect gas with a symmetric mean temperature profile is studied for subsonic Mach numbers in the high Reynolds number limit where viscous and thermal diffusion effects enter first and dominate in the critical layer. The linear, neutral eigensolution of the inviscid theory for temperature profiles having either an excess or deficit of mean temperature in the shear layer is used as a basis for the weakly nonlinear, slightly viscous analysis. The coefficients of viscosity and thermal conductivity are assumed to have a power-law dependence on the temperature and the effect of viscous dissipation is included. An analytical expression for the Landau constant, and other constants appearing in the nonlinear evolution equation for the amplitude of the eigenmode, have been obtained. It is found that the temperature excess of deficit at the critical level and the Mach number have a strong nonlinear effect, even to the extent of changing the sign of the Landau constant.

Author

**A90-20508#**

**PARABOLIZED NAVIER-STOKES PREDICTIONS OF THREE-DIMENSIONAL HYPERSONIC FLOWS WITH STRONG CROSSFLOW EFFECTS**

BILAL A. BHUTTA and CLARK H. LEWIS (VRA, Inc., Blacksburg, VA) Journal of Thermophysics and Heat Transfer (ISSN 0887-8722), vol. 4, Jan. 1990, p. 27-36. Previously cited in issue 20, p. 3340, Accession no. A88-47989. refs

Copyright

**A90-20988**

**TRANSONIC INTEGRO-DIFFERENTIAL AND INTEGRAL EQUATIONS WITH ARTIFICIAL VISCOSITY**

W. OGANA (Nairobi, University, Kenya) Engineering Analysis with Boundary Elements (ISSN 0955-7997), vol. 6, Sept. 1989, p. 129-135. refs

Copyright

From the two-dimensional transonic small disturbance equation with artificial viscosity, an integrodifferential equation and subsequently an integral equation are derived. The computational domain is discretized into rectangular elements and functions of the dependent variable and its derivatives are assumed to be constant in each element. The resulting nonlinear algebraic systems are solved by Jacobi iteration. The method is tested for parabolic-arc and NACA0012 airfoils. Convergence is fast and the solutions compare well with finite-difference results, despite the use of a comparably small number of nodes.

Author

**A90-21026#**

**HYDRODYNAMIC VISUALIZATION OF ORGANIZED STRUCTURES AND TURBULENCES IN BOUNDARY LAYERS, WAKES, JETS OR PROPELLER FLOWS**

H. WERLE (International Conference on Turbulence, Grenoble, France, Sept. 18-21, 1989) ONERA, TP no. 1989-158, 1989, 11 p. refs

(ONERA, TP NO. 1989-158)

This paper reviews some typical examples of water tunnel visualizations made at ONERA using liquid and gaseous tracers injected directly into the flows. The water tunnel visualizations reveal certain turbulence and the mechanisms responsible for organized structures that occur in boundary layers, wakes, jets,

and propeller flows. These visualizations demonstrate chiefly the time variation in the organized structures, as well as the contribution of certain parameters such as the Reynolds number. I.S.

**A90-21029#**

**INVISCID NON EQUILIBRIUM FLOW IN ONERA F4 WIND TUNNEL**

CYRIL FLAMENT, LUC LE TOULLEC, LIONEL MARRAFFA, and PHILIPPE SAGNIER (ONERA, Chatillon-sous-Bagneux, France) (International Conference on Hypersonic Aerodynamics, Manchester, England, Sept. 4-6, 1989) ONERA, TP no. 1989-161, 1989, 14 p. refs

(ONERA, TP NO. 1989-161)

A parametric study is performed on the hypersonic flow through the future ONERA F4 wind tunnel. Two pseudomonodimensional codes are used to compute the chemical and vibrational nonequilibrium inviscid flow through the nozzle: an explicit steady space-marching code and an implicit unsteady code. The results of the two codes are compared for a given configuration, and the influence of different physicochemical models is investigated.

Author

**A90-21033**

**RECENT DEVELOPMENTS IN CALCULATION METHODS FOR INTERNAL FLOWS BY SOLUTION OF EULER OR NAVIER-STOKES EQUATIONS [DEVELOPPEMENTS RECENTS SUR LES METHODES DE CALCUL D'ECOULEMENTS INTERNES PAR RESOLUTION DES EQUATIONS D'EULER OU DE NAVIER-STOKES]**

L. CAMBIER, J. P. VEUILLLOT, and A. M. VUILLLOT (ONERA, Chatillon-sous-Bagneux, France) (Revue Francaise de Mecanique, no. 4, 1988, p. 11-26) ONERA, TP no. 1989-167, 1989, 17 p. In French. Research supported by DRET and SNECMA. refs

(ONERA, TP NO. 1989-167) Copyright

This paper presents studies carried out at the Aerodynamics Department of ONERA for the calculation of internal flows by solution of the Euler equations (inviscid flows) or of the Reynolds-averaged Navier-Stokes equations (viscous flows). The numerical method is described, characterized by the use of a centered explicit finite-difference scheme combined with a multigrid convergence-acceleration technique, and by a multidomain approach. Numerical results are presented for calculations of transonic inviscid and turbulent viscous flows in a plane supersonic compressor cascade. Results are also presented for the calculation of a three-dimensional inviscid flow in a turbine stator.

Author

**A90-21036#**

**DEVELOPMENT OF THE MZM NUMERICAL METHOD FOR 3D BOUNDARY LAYER WITH INTERACTION ON COMPLEX CONFIGURATIONS**

M. LAZAREFF and J. C. LE BALLEUR (ONERA, Chatillon-sous-Bagneux, France) (Gesellschaft fuer Angewandte Mathematik und Mechanik, Conference on Numerical Methods in Fluid Mechanics, 8th, Delft, Netherlands, Sept. 27-29, 1989) ONERA, TP no. 1989-174, 1989, 11 p. refs

(ONERA, TP NO. 1989-174)

The viscous three-dimensional steady flow problem at high Reynolds number is simplified to a viscous-defect problem coupled with a pseudoinviscid problem. The viscous-defect problem is hyperbolic along the boundaries under thin-layer assumptions. The viscous-defect problem is solved by a hybrid field/integral method using modeled three-dimensional parametric velocity profiles, discretized in the normal direction. The multizonal marching numerical method (Lazareff and Balleur, 1985) is extended for complex multistructured configurations. This method is applied to wings in attached flows, ellipsoids at incidence, and aircraft wing-body configurations.

R.B.

**A90-21037#**

**CHEMICAL AND VIBRATIONAL NON-EQUILIBRIUM NOZZLE FLOW CALCULATION BY AN IMPLICIT UPWIND METHOD**

C. FLAMENT (ONERA, Chatillon-sous-Bagneux, France) (Gesellschaft fuer Angewandte Mathematik und Mechanik,

## 02 AERODYNAMICS

Conference on Numerical Methods in Fluid Mechanics, 8th, Delft, Netherlands, Sept. 27-29, 1989) ONERA, TP no. 1989-175, 1989, 11 p. refs  
(ONERA, TP NO. 1989-175)

The equations governing chemical and vibrational non-equilibrium nozzle flows are first presented. The resulting differential system is then discretized using a fully implicit noncentered finite-volume approach. The method is finally applied to two different hypersonic-nozzle geometries. Results are compared with equilibrium as well as previous space-marching calculations. Author

**A90-21045\*** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **CORRELATION OF PUMA AIRFOILS - EVALUATION OF CFD PREDICTION METHODS**

ROGER C. STRAWN (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA), ANDRE DESOPPER (ONERA, Chatillon-sous-Bagneux, France), JUDITH MILLER, and ALAN JONES (Royal Aerospace Establishment, Farnborough, England) (European Rotorcraft Forum, 14th, Amsterdam, Netherlands, Sept. 12-15, 1989) ONERA, TP no. 1989-185, 1989, 20 p. Previously announced in STAR as N89-28498. refs  
(ONERA, TP NO. 1989-185)

A cooperative program was undertaken by research organizations in England, France, Australia and the U.S. to study the capabilities of computational fluid dynamics codes (CFD) to predict the aerodynamic loading on helicopter rotor blades. The program goal is to compare predictions with experimental data for flight tests of a research Puma helicopter with rectangular and swept tip blades. Two topics are studied. First, computed results from three CFD codes are compared for flight test cases where all three codes use the same partial inflow-angle boundary conditions. Second, one of the CFD codes (FPR) is iteratively coupled with the CAMRAD/JA helicopter performance code. These results are compared with experimental data and with an uncoupled CAMRAD/JA solution. The influence of flow field unsteadiness is found to play an important role in the blade aerodynamics. Alternate boundary conditions are suggested in order to properly model this unsteadiness in the CFD codes. Author

**A90-21159\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

### **EFFECTS OF THERMOCHEMISTRY, NONEQUILIBRIUM, AND SURFACE CATALYSIS ON THE DESIGN OF HYPERSONIC VEHICLES**

CARL D. SCOTT (NASA, Johnson Space Center, Houston TX) IN: Hypersonics. Volume 1 - Defining the hypersonic environment; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 355-427. refs  
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An account is given of the function of physical aspects of a gas on the characteristics of the flow and of the heating associated with hypersonic flight. At the high temperatures encountered, the thermal and chemical characteristics of the air in a hypersonic vehicle's shock layer are altered in ways which depend on the atomic and molecular structure of N and O and their ions; similar effects exist in scramjet propulsion systems. These properties in turn influence the character of shock waves and expansions, and hence the pressure, temperature, and velocity distributions. Transport properties affecting the boundary-layer structure will also affect heat flux and shear stress. O.C.

### **A90-21163 RAREFIED GAS DYNAMICS**

G. KOPPENWALLNER (DLR, Institut fuer experimentelle Stromungsmechanik, Goettingen, Federal Republic of Germany) IN: Hypersonics. Volume 1 - Defining the hypersonic environment; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA,

Birkhaeuser, 1989, p. 511-547. refs  
Copyright

An account is given of the fundamental features of the rarefied flow regimes, with a view to gas surface interaction and its influence on the flow. An analysis is also conducted of the hypersonic aerodynamic behavior of simple-shaped bodies over the range of flows extending from the molecular (very high altitudes) to the continuum (lower altitudes). The analysis encompasses the roles played by forces, heat transfer, and flow fields, and attempts to account for observed rarefaction phenomena. Both drag-generating and combined lift-and-drag-generating bodies are considered. O.C.

### **A90-21164 HYPERSONICS. VOLUME 2 - COMPUTATION AND MEASUREMENT OF HYPERSONIC FLOWS; PROCEEDINGS OF THE FIRST JOINT EUROPE/U.S. SHORT COURSE ON HYPERSONICS, PARIS, FRANCE, DEC. 7-11, 1987**

JOHN J. BERTIN, ED. (Texas, University, Austin), ROLAND GLOWINSKI, ED. (Houston, University, TX), and JACQUES PERIAUX, ED. (AMDBA, S.A., Saint-Cloud, France) Course sponsored by NATO, DRET, U.S. Navy, et al. Boston, MA, Birkhaeuser (Progress in Scientific Computing, Volume 9), 1989, 468 p. For individual items see A90-21165 to A90-21171. Copyright

The present volume discusses state-of-the-art engineering approaches to hypersonic flow-field computations, calculations of hypersonic laminar boundary layers, leading-edge transitions in hypersonic flows, and special techniques and real gas effects in computational methods for hypersonic flows. Also discussed are hypersonic flow computations conducted by finite-volume methods, the computation of hypersonic viscous flows, computation methods for hypersonic flow fields, and the state-of-the-art in hypersonic flight testing. O.C.

### **A90-21167 LEADING EDGE TRANSITION IN HYPERSONIC FLOWS**

T. ALZIARY DE ROQUEFORT (Poitiers, Universite, France) IN: Hypersonics. Volume 2 - Computation and measurement of hypersonic flows; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 151-180. refs  
Copyright

This paper deals with a particular type of transition, namely attachment line contamination. The laminar flow in the vicinity of the attachment line on a swept circular cylinder is described. A review of experimental work on leading edge transition is presented together with POLL's criterion and its extension to compressible flow. Then an experimental investigation of transition at Mach 7.1 on a swept circular cylinder is described. The occurrence of transition is detected by an increase of the Stanton number and details on the experimental techniques used to measure heat fluxes are given. The influence of wall temperature and of the length of streamwise end plates is discussed. Finally, new promising experimental techniques based on laser induced fluorescence or Rayleigh diffusion of infrared light are briefly described. Author

### **A90-21168 COMPUTATIONS OF HYPERSONIC FLOW BY FINITE-VOLUME METHODS**

ARTHUR RIZZI (Flygtekniska Forsoksanstalten, Bromma, Sweden) IN: Hypersonics. Volume 2 - Computation and measurement of hypersonic flows; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 247-287. refs  
Copyright

The present account of principles for the application of the finite-volume method to the problem of an inviscid, chemically-reacting flow focuses on the blunt-body problem governed by the Euler equations, in conjunction with a five-reaction chemistry model for air. Emphasis is given to the solution of the complete problem of chemistry coupled with the solution to the Euler equations. A splitting into two separate operators is employed

to effectively solve the stiff equations of chemical nonequilibrium. Illustrative applications noted encompass hypersonic flow past three-dimensional blunt bodies and a blunt delta wing. O.C.

**A90-21169\*** National Aeronautics and Space Administration. Lyndon B. Johnson Space Center, Houston, TX.

#### COMPUTATION OF HYPERSONIC FLOW FIELDS

CHIEN-PENG LI (NASA, Johnson Space Center, Houston, TX) IN: Hypersonics. Volume 2 - Computation and measurement of hypersonic flows; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 289-411. refs  
Copyright

The present discussion of the theory, solution methods, and development status of chemically reactive flow CFD codes pertaining to the flow field around a hypersonic vehicle encompasses the formulation of multicomponent viscous equations, grid-generation techniques, and finite-difference algorithms. The Navier-Stokes equations presented focus on such particularities of high speed vehicles as their aerodynamic configuration, lee and wake flow, bow shock, and chemistry and low density effects. Issues for which further development is desirable encompass boundary treatments, grid quality, shock capturing, and the decoupling of chemistry from flow variables. O.C.

**A90-21170**

#### ON THE COMPUTATIONS OF HYPERSONIC VISCOUS FLOWS

D. HAENEL and R. SCHWANE (Aachen, Rheinisch-Westfaelische Technische Hochschule, Federal Republic of Germany) IN: Hypersonics. Volume 2 - Computation and measurement of hypersonic flows; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 413-430. refs  
Copyright

A computational method initially developed for the two-dimensional Navier-Stokes equations, which is sufficiently accurate in viscous flow while maintaining high resolution in the nearly-inviscid portion of the flow, is presently extended to three dimensions. A detailed examination is made of the solution method for the three-dimensional Navier-Stokes equations and the thin layer approximation. The method is combined with a shock-fitting procedure, and grid generation is accomplished by means of an iterative optimization procedure. Illustrative computational results are presented. O.C.

**A90-21475**

#### ADVANCES IN THE EFFICIENT CALCULATION OF FLOWS WITH FRICTION [FORTSCHRITTE BEI DER EFFIZIENTEN BERECHNUNG VON STROEMUNGEN MIT REIBUNG]

ROLF RADESPIEL and CORD-CHRISTIAN ROSSOW (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), Nov. 1989, p. 79-82. In German.  
Copyright

Thanks to recent advances in the calculation of flow equations, calculative methods can now be used to solve the Navier-Stokes equations used in the design of profiles and airfoils. In this paper, some advances that have been made in the efficient calculation of flows with friction are discussed. A mathematical model used in the solution procedures is described. C.D.

**A90-21592**

#### THE USE OF A LAVAL NOZZLE AND WALL SUCTION FOR BLOCKAGE-FREE TRANSONIC WIND-TUNNEL OPERATION [DER EINSATZ VON LAVALDUESE UND WANDABSAUGUNG FUER BLOCKIERUNGSFREIEN, TRANSSONISCHEN WINDKANALBETRIEB]

S. WAGNER and H. SCHEITL (Muenchen, Universitaet der Bundeswehr, Neubiberg, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, Nov.-Dec. 1989, p. 344-350. In German. refs  
Copyright

Mach numbers between 0.3 and 3 can be obtained at the transonic wind tunnel of the Universitaet der Bundeswehr in Munich. As in other wind tunnels, the blockage characteristics of the model lead to effects which impede the operation at Mach numbers near unity. By using both a Laval nozzle and wall suction, this blockage is avoided, ensuring incident flow velocities over the whole transonic range. Pressure measurements and schlieren photographs verify this. Author

**A90-21593**

#### A PARAMETRIC STUDY OF THE FLUTTER STABILITY OF TWO-DIMENSIONAL TURBINE AND COMPRESSOR CASCADES IN INCOMPRESSIBLE FLOW

H. FOERSCHING (DLR, Institut fuer Aeroelastik, Goettingen, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, Nov.-Dec. 1989, p. 351-364.  
Copyright

A systematic parametric investigation of the flutter behavior of two-dimensional axial-flow turbomachine cascades in inviscid incompressible flow is performed. The equations of motion of the blading are set up in generalized form and the concept of traveling waves for a dynamically perfectly tuned cascade and the relating aerodynamic model are then discussed. Based on this concept, the corresponding aeroelastic stability equations for the study of single mode flutter with kinematically coupled bending and torsion are next derived in non-dimensional form for a typical two-dimensional section model. Numerical results are presented for a variety of systematic parameter variations for both turbine and compressor cascades and overall trends in the aeroelastic stability of rectilinear cascades and the effects of the dominant parameters are pointed out. Author

**A90-21595**

#### CALCULATION OF THE SIDE-WALL BOUNDARY LAYER IN AXIAL TURBOMACHINES, ACCOUNTING FOR THE INTERNAL FLOW NEAR THE BLADES [BERECHNUNG DER SEITENWANDGRENZSCHICHT IN AXIALEN TURBOMASCHINEN UNTER BERUECKSICHTIGUNG DER INNENSTROEMUNG IM SCHAUFELBEREICH]

M. SCHWARZ, W. VOLGMANN, and K. G. GRAHL (Bochum, Ruhr-Universitaet, Federal Republic of Germany) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, Nov.-Dec. 1989, p. 371-376. In German.  
Copyright

In a computer program to calculate the flow in multistage axial compressors, the wall boundary layers are predicted by an integral method. Previously this calculation has only provided information on the boundary layer at outlet from the blade passages; in the current version, it is possible to consider the nonlinear development of the parameters inside the blade passage. A detailed investigation of the secondary flow was made with the help of a three-dimensional finite-volume code. Using data from the stators and rotors of a three-stage compressor, correlations were found which could be used to calculate the secondary flow. Author

**A90-21596**

#### NUMERICAL SIMULATION OF TRANSONIC WING FLOWS USING A ZONAL EULER, BOUNDARY-LAYER, NAVIER-STOKES APPROACH

M. A. SCHMATZ, F. MONNOYER, and K. M. WANIE (MBB GmbH, Munich, Federal Republic of Germany) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988) Zeitschrift fuer Flugwissenschaften und Weltraumforschung (ISSN 0342-068X), vol. 13, Nov.-Dec. 1989, p. 377-384. refs  
Copyright

A zonal solution procedure is applied to compute three-dimensional flow fields past a generic transport aircraft type wing. The main feature of the zonal method is the coupling of local solutions of the Navier-Stokes equations with an equivalent inviscid flow and a second order boundary-layer solution in their regions of validity. The zonal boundaries are adaptively rezoned during the iteration. The code is based on the well proven NSFLEX



code, which is an upwind relaxation method for the Navier-Stokes equations. The zonal method used gives a gain in accuracy in the boundary-layer region and more rapid convergence. Author

**A90-21626#**

### **A CALCULATION METHOD FOR DUCTED PROPELLERS [METODA OBLICZANIA SMIGLA TUNELOWEGO]**

STANISLAW KUCZEWSKI Technika Lotnicza i Astronautyczna (ISSN 0040-1145), vol. 44, July 1989, p. 3-7. In Polish.

A calculation and design method for ducted propellers is presented. The method can be used to determine the optimal shape of the propeller at a given power and speed, and to establish thrust at flight speeds ranging from takeoff speed to maximum speed. The method is convenient for computer use. B.J.

### **A90-21935\*# Vigyan Research Associates, Inc., Hampton, VA. PREDICTION OF VORTICAL FLOWS ON WINGS USING INCOMPRESSIBLE NAVIER-STOKES EQUATIONS**

C.-H. HSU (Vigyan Research Associates, Inc., Hampton, VA) and C. H. LIU (NASA, Langley Research Center, Hampton, VA) International Congress of Fluid Mechanics, 3rd, Cairo, Egypt, Jan. 2-4, 1990, Paper. 15 p. refs

Numerical solutions to the incompressible Navier-Stokes equations are in greater demand than ever before as the field of computational fluid dynamics (CFD) increases its impact as an engineering tool. An implicit upwind-relation finite-difference scheme is developed for solving unsteady incompressible Navier-Stokes equations incorporating an artificial time derivative of the pressure to the continuity equation. The essential features observed in experiments for complicated vortical flows past three round-edged low-aspect-ratio wings at high angles of attack are reproduced both qualitatively and quantitatively. Author

**A90-21946**

### **A FINITE ELEMENT SOLUTION OF UNSTEADY TWO-DIMENSIONAL FLOW IN CASCADES**

D. S. WHITEHEAD (Cambridge, University, England) International Journal for Numerical Methods in Fluids (ISSN 0271-2091), vol. 10, Jan. 1990, p. 13-34. refs  
Copyright

A theory is presented for unsteady two-dimensional potential transonic flow in cascades of compressor and turbine blades using a mesh of triangular finite elements. The theory leads to a computer program, FINSUP, which is fast and has moderate storage requirements, so that it can be run on a personal computer. Comparisons with other theories in special cases show that the program is accurate in subsonic flow, and that in supersonic flow, although the wave effects are smeared by the numerical process, the results for overall blade force and moment have acceptable accuracy. The program is useful for engineering assessment of unstalled flutter of actual compressor and turbine blades. Author

**A90-21983#**

### **THE DISTRIBUTION OF NORMAL-WASH FOR MINIMUM INDUCED DRAG OF NON-PLANAR WINGS**

RENLIANG ZHOU (Nanjing Aeronautical Institute, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, Nov. 1989, p. A595-A597. In Chinese, with abstract in English.

The formulas of normal-wash for minimum induced drag of non-planar wings having a given lift and bending moment are presented in this paper. The distribution of optimum loading for non-planar wings with restricted lift and bending moment can be determined by these formulas. Author

**A90-21984#**

### **A FINITE ELEMENT METHOD FOR SOLVING LIFTING AIRFOIL IN TRANSONIC FLOW**

XIANPING LI and GUOFU ZHANG (Nanjing Aeronautical Institute, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, Nov. 1989, p. A598-A602. In Chinese, with abstract in English.

An FEM for solving minimum pressure integral potential

equations is applied to solve lifting airfoils in transonic flow. Two solutions corresponding to zero and unit circulation are combined at each iteration so that the result satisfies the Kutta condition. This condition at the trailing edge requires that the streamline leaving the trailing edge be tangent to its bisector. Since the FEM does not require that the grid line be orthogonal, a sequence of shearing and stretching transformations, both prior to and subsequent to the elliptic mapping, is used. The grid generation method can easily generate finite element meshes about complex geometries. The artificial compressibility method stabilizes the algorithm in transonic flow and permits the capture of embedded shock waves. The results are compared with existing experimental measurement and other numerical solutions. C.D.

**A90-22153\*# Georgia Inst. of Tech., Atlanta.**

### **APPLICATION OF AN EFFICIENT HYBRID SCHEME FOR AEROELASTIC ANALYSIS OF ADVANCED PROPELLERS**

R. SRIVASTAVA, N. L. SANKAR (Georgia Institute of Technology, Atlanta), T. S. R. REDDY (Toledo, University, OH), and D. L. HUFF (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 29 p. Previously announced in STAR as N90-13355. refs  
(Contract NAG3-730)

(AIAA PAPER 90-0028) Copyright

An efficient 3-D hybrid scheme is applied for solving Euler equations to analyze advanced propellers. The scheme treats the spanwise direction semi-explicitly and the other two directions implicitly, without affecting the accuracy, as compared to a fully implicit scheme. This leads to a reduction in computer time and memory requirement. The calculated power coefficients for two advanced propellers, SR3 and SR7L, and various advanced ratios showed good correlation with experiment. Spanwise distribution of elemental power coefficient and steady pressure coefficient differences also showed good agreement with experiment. A study of the effect of structural flexibility on the performance of the advanced propellers showed that structural deformation due to centrifugal and aero loading should be included for better correlation. Author

**A90-22154#**

### **COMPUTATION OF SUBSONIC SHROUDED PROPELLER FLOWS**

WALTER O. VALAREZO (Douglas Aircraft Co., Long Beach, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. Research sponsored by the McDonnell Douglas Independent Research and Development Program. refs  
(AIAA PAPER 90-0029) Copyright

A surface panel method for the computation of subsonic shrouded propeller flows is presented. The method is an extension of a previously developed and highly successful steady propeller method and solves for the flow on the propeller and the shroud simultaneously. Features of the present method are described and results showing the effect of the shroud on blade loading are presented for a variety of conditions. The computed effects of tip-to-shroud gap size on the propeller as well as the shroud are also investigated using this method. Author

**A90-22155#**

### **SUBSONIC CALCULATION OF PROPELLER/WING INTERFERENCE**

ROGER W. CLARK and WALTER O. VALAREZO (Douglas Aircraft Co., Long Beach, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 6 p. Research sponsored by the McDonnell Douglas Independent Research and Development Program. refs

(AIAA PAPER 90-0031) Copyright

The design of transport aircraft with vertical takeoff and landing capability requires the modeling of the power effects on an aircraft configuration. An approach is presented here in which the interaction between a propeller slipstream and a lifting wing is computed. This method makes use of a general three-dimensional panel method to compute the aircraft flowfield, together with a propeller panel method in which the flow over an isolated propeller

is computed. These two methods are coupled so that the wing flowfield in the presence of the propeller can be computed. Results are presented comparing the present method with experimental data for a tractor-mounted propeller. The results obtained show that the panel method approach can be used to predict the propeller/wing interference for a propeller mounted ahead of the wing. Author

**A90-22156\*#** Sterling Software, Palo Alto, CA.  
**CALCULATIONS OF THE FLOW PAST BLUFF BODIES, INCLUDING TILT-ROTOR WING SECTIONS AT  $\alpha = 90^\circ$  DEG**

V. RAGHAVAN (Sterling Software, Palo Alto, CA), W. J. MCCROSKEY, J. D. BAEDER (NASA, Ames Research Center; U.S. Army, Aeroflightdynamics Directorate, Moffett Field, CA), and W. R. VAN DALSEM (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 14 p. refs  
 (AIAA PAPER 90-0032) Copyright

An attempt was made to model in two dimensions the effects of rotor downwash on the wing of the tilt-rotor aircraft and to compute the drag force on airfoils at  $-90^\circ$  deg angle of attack, using a well-established Navier-Stokes code. However, neither laminar nor turbulent calculations agreed well with drag and base-pressure measurements at high Reynolds numbers. Therefore, further efforts were concentrated on bluff-body flows past various shapes at low Reynolds numbers, where a strong vortex shedding is observed. Good results were obtained for a circular cylinder, but the calculated drag of a slender ellipse at right angles to the freestream was significantly higher than experimental values reported in the literature for flat plates. Similar anomalous results were obtained on the tilt-rotor airfoils, although the qualitative effects of flap deflection agreed with the wind tunnel data. The ensemble of results suggest that there may be fundamental differences in the vortical wakes of circular cylinders and noncircular bluff bodies. Author

**A90-22161#**  
**EFFECTS OF PRESSURE MISMATCH ON SLOT INJECTION IN SUPERSONIC FLOW**

J. A. SCHETZ, F. S. BILLIG, S. FAVIN, and H. E. GILREATH (Johns Hopkins University, Laurel, MD) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. Research supported by the U.S. Navy. refs  
 (AIAA PAPER 90-0092) Copyright

The effect of pressure mismatch on the slot injection flow field in supersonic flows was studied using a simplified analysis of cases with initial pressure mismatch for tangential slot injection into a hypersonic (or supersonic) external flow having a thick turbulent initial boundary layer. The analysis uses hypersonic (or supersonic) small disturbance theory, a power law shape for the initial boundary layer velocity profile and a Crocco integral to obtain the temperature profile, a turbulent entrainment model including the effect of a convective Mach number, a quasi-one-dimensional assumption in the mixing and burning region, an instantaneous heat release model, and simple models of skin friction and heat transfer. The comparisons of prediction and experiment and the results of parametric calculations indicate that a pressure mismatch produces considerable complications of slot injection flow fields. The present analysis correctly predicted the major effects of a mismatch in situations where the ratio of the jet-exit-flow pressure to the external-flow pressure is between 0.8 and 1.25. I.S.

**A90-22164\*#** Stanford Univ., CA.  
**PNEUMATIC VORTICAL FLOW CONTROL AT HIGH ANGLES OF ATTACK**

DOMINGO A. TAVELLA (Stanford University, CA), LEWIS B. SCHIFF, and RUSSELL M. CUMMINGS (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 14 p. refs  
 (AIAA PAPER 90-0098) Copyright

The injection of thin, high-momentum jets of air into the fuselage forebody boundary layers of the F-18 aircraft is explored numerically

as a means of controlling the onset of fuselage vortices and of generating yaw control forces. The study was carried out for an angle of attack of  $30^\circ$  deg with symmetrical and asymmetrical blowing configurations. One-sided blowing results in a strongly asymmetrical flow pattern in the fore portion of the fuselage, leading to a net lateral force. Author

**A90-22165\*#** National Aeronautics and Space Administration.  
 Ames Research Center, Moffett Field, CA.

**NAVIER-STOKES PREDICTIONS OF THE FLOWFIELD AROUND THE F-18 (HARV) WING AND FUSELAGE AT LARGE INCIDENCE**

RUSSELL M. CUMMINGS, YEHIA M. RIZK, LEWIS B. SCHIFF, and NEAL M. CHADERJIAN (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 23 p. refs  
 (AIAA PAPER 90-0099) Copyright

In support of the NASA High Alpha Technology Program, Navier-Stokes solutions have been obtained using the Chimera overset grid scheme for flow over the wing, fuselage, and wing leading-edge extension (LEX) of the F/A-18 High Alpha Research Vehicle (HARV) at high incidence. Solutions are also presented for flow over the fuselage forebody at high angles of attack. The solutions are for turbulent flows at high-Reynolds-number flight-test conditions, and are compared with available qualitative and quantitative experimental data. Comparisons of predicted surface flow patterns, off-surface flow visualization, and surface-pressure distributions are in good agreement with flight-test data. The ability of the numerical method to predict the bursting of the LEX vortex as it encounters the adverse pressure gradient field of the wing is demonstrated, and the capability of predicting high-angle-of-attack aerodynamics around realistic aircraft configurations is established. Author

**A90-22166\*#** National Aeronautics and Space Administration.  
 Ames Research Center, Moffett Field, CA.

**VORTICAL FLOWS OVER DELTA WINGS AND NUMERICAL PREDICTION OF VORTEX BREAKDOWN**

J. A. EKATERINARIS (U.S. Navy-NASA Joint Institute of Aeronautics, Moffett Field, CA) and LEWIS B. SCHIFF (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 23 p. Research sponsored by the U.S. Navy. refs  
 (AIAA PAPER 90-0102) Copyright

Navier-Stokes solutions of subsonic vortical flow over a  $75^\circ$  deg sweep delta wing with a sharp leading edge are presented. The sensitivity of the solution to the numerical scheme is examined using both a partially upwind scheme and a scheme with central differencing in all directions. At moderate angles of attack, no vortex breakdown is observed, whereas the higher angle-of-attack cases exhibit breakdown. The effect of numerical grid density is investigated, and solutions that are obtained with various grid densities are compared with experimental data. An embedded grid approach is implemented to enable higher resolution in selected isolated flow regions, such as the leeward-side surface, the leading-edge vortical flow, and the vortex breakdown region. C.D.

**A90-22167#**  
**AN INVESTIGATION OF ASYMMETRIC VORTICAL FLOWS OVER DELTA WINGS WITH TANGENTIAL LEADING-EDGE BLOWING AT HIGH ANGLES OF ATTACK**

ZEKI Z. CELIK, LEONARD ROBERTS (Stanford University, CA), and N. J. WOOD (Bath, University, England) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 9 p. Research supported by USAF. refs  
 (AIAA PAPER 90-0103) Copyright

An experimental investigation has been carried out to determine the ability of tangential leading edge blowing to stabilize and control the flow asymmetries and instabilities that occur over a delta wing at high angles of attack. Steady state force, moment and pressure data have been obtained for a variety of pitch, roll and yaw configurations for prestall and poststall angles of attack. The rolling

moment at poststall angles is reversed compared to prestall angles of attack. Asymmetric blowing is capable of producing roll control for poststall angles of attack.. Author

**A90-22186#**

### **A NUMERICAL METHOD FOR THREE-DIMENSIONAL VISCOUS FLOWS**

C. M. WANG and J. C. WU (Georgia Institute of Technology, Atlanta) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. Research supported by the U.S. Army. refs  
(AIAA PAPER 90-0236) Copyright

A zonal procedure based on the vorticity-velocity formulation is extended to treat three-dimensional general viscous flows. The generation or depletion of the vorticity on solid surface is evaluated using kinematic constraints. Numerical solutions of flat-plate wings at different aspect ratio and angle of attack obtained using the zonal procedure are presented and discussed. Author

**A90-22195\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **SIMULATION AND ANALYSIS OF A DELTA PLANFORM WITH MULTIPLE JETS IN GROUND EFFECT**

K. CHAWLA, W. R. VAN DALSEM, and K. V. RAO (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 17 p. refs  
(AIAA PAPER 90-0299) Copyright

The three-dimensional, thin-layer Navier-Stokes equations on a body-conforming, overset, multiple-grid topology are solved in the present numerical simulations of the flow around a 60-deg delta-planform wing equipped with two thrust-reverser jets in ground-effect conditions. Such experimentally flow-visualized features as jet-deformation and ground vertex-formation are captured by these simulations; the loss of wing-borne lift due to the 'suck-down' phenomenon, which arises as the delta planform flies at low speeds in close proximity to the ground, is also well simulated. O.C.

**A90-22196\*#** California Univ., Davis.

### **WIND-TUNNEL INVESTIGATION ON THE EFFECT OF A CRESCENT PLANFORM ON DRAG**

C. P. VAN DAM (California, University, Davis), P. M. H. W. VIJGEN (High Technology Corp., Hampton, VA), and B. J. HOLMES (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 17 p. refs  
(Contract NAG1-732; NCA2-397; NAS1-18240)  
(AIAA PAPER 90-0300)

Lift and drag forces were compared for elliptic and crescent wing models at cruise and climb conditions in the NASA/Langley 14 x 22-ft subsonic tunnel. The force measurements were obtained for an angle-of-attack range from -3 to 10 deg at a Reynolds number of about 1.7 million. The results indicate that for attached flow conditions, the crescent wing with its highly swept tips generates less lift-dependent drag than the elliptic wing for given lift force, wing span, and freestream conditions. The drag reduction is thought to be the result of the favorable influence of trailing wake deformations on the pressure distribution of the highly swept outboard region of the crescent wing. Author

**A90-22197\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **UNSTEADY TRANSONIC NAVIER-STOKES COMPUTATIONS FOR AN OSCILLATING WING USING SINGLE AND MULTIPLE ZONES**

NEAL M. CHADERJIAN and GURU P. GURUSWAMY (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs  
(AIAA PAPER 90-0313) Copyright

Modern jet transports and maneuvering tactical fighters operating in the transonic regime often give rise to time-dependent fluid physics that interact with flexible structural components, e.g., vortical flow, shocks, and separation. Efficient computational fluid dynamic (CFD) methods are required to study such computationally

intensive problems. In this work a numerical method is presented to address this problem. Time-dependent, compressible, Navier-Stokes equations are used to simulate unsteady transonic flow about a three-dimensional rigid wing undergoing a forced periodic motion in angle of attack. An efficient, implicit, diagonal algorithm is utilized because of its low operation count per time step compared to other methods that solve systems of block matrix equations. The formal time accuracy is addressed theoretically and demonstrated numerically by comparison of computational results with experimental data. A zonal grid approach, capable of treating complex geometries, is presented and its time accuracy is demonstrated by comparing a zonal computation with a single grid computation and experimental data. Author

**A90-22207#**

### **SWEPT SHOCK/BOUNDARY-LAYER INTERACTIONS - TUTORIAL AND UPDATE**

G. S. SETTLES (Pennsylvania State University, University Park) and D. S. DOLLING (Texas, University, Austin) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 30 p. refs  
(AIAA PAPER 90-0375) Copyright

This paper presents a brief tutorial on the results of over two decades of research on swept shock/boundary-layer interactions by numerous investigators, with special emphasis on an update of the last five years' work. Attention is concentrated primarily on the simplest of all dimensionless interactions, i.e., that generated by a flat-plate turbulent boundary layer interacting with the swept, planar oblique shock wave generated by an upright, sharp-leading-edged fin at angle-of-attack  $\alpha$ . An overall similarity framework for the behavior of such swept interactions is the subject of the first several sections of the paper, where the symmetry and structure of the mean interaction are explored and the relative influences of  $\alpha$ , Mach number, Reynolds number, and boundary-layer thickness are accounted for. This is followed by a discussion of the fundamentally-unsteady nature of shock boundary layer interactions. Computational efforts in which swept interactions currently pace code validation are then discussed. Finally, the control of these interactions is examined. Author

**A90-22208#**

### **SPANWISE PROPERTIES OF THE UNSTEADY SEPARATION SHOCK IN A MACH 5 UNSWEPT COMPRESSION RAMP INTERACTION**

T. A. MARSHALL (Lockheed Engineering and Sciences Co., Houston, TX) and D. S. DOLLING (Texas, University, Austin) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 14 p. refs  
(Contract AF-AFOSR-86-0112)  
(AIAA PAPER 90-0377) Copyright

Literature reports show that the comparison between experiment and computation for highly separated unswept compression ramp flows is poor irrespective of the turbulence model used. This paper examines the reason for such discrepancies. Wall pressure fluctuations were measured under the unsteady separation shock wave in a 28-deg unswept compression ramp flow at Mach 5, using up to eight transducers oriented streamwise or spanwise at various transducer spacings, using conditionally sampled pressure signals to generate 'snapshots' or 'frames' of the instantaneous separation shock front passing over the transducer array. Results show that the distribution of time-averaged surface properties of the separation shock front is controlled by the large-scale low-frequency separation-shock unsteadiness, indicating that the primary cause of the discrepancies is neglect of the flow-field unsteadiness. I.S.

**A90-22210#**

### **AN EXPERIMENTAL INVESTIGATION OF SWEEP-ANGLE INFLUENCE ON DELTA-WING FLOWS**

FREDERICK W. ROOS and JEROME T. KEGELMAN (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs



(Contract N62269-86-C-0284)  
(AIAA PAPER 90-0383) Copyright

The leading-edge-vortex flowfields over 60 and 70 degree delta wings have been studied. Measurements include vortex trajectories and burst locations, aerodynamic loads, and leeward-surface pressures. Pressure distributions clearly document the increasing influence of the leading-edge vortex with increasing angle of attack, the broadening of the suction peak when the vortex bursts, and the collapse of organized vortex flow when stall occurs. Author

**A90-22213\*** Imperial Coll. of Science and Technology, London (England).

**APPLICATIONS OF AN ADAPTIVE UNSTRUCTURED SOLUTION ALGORITHM TO THE ANALYSIS OF HIGH SPEED FLOWS**

R. R. THAREJA, R. K. PRABHU (Lockheed Engineering and Sciences Co., Hampton, VA), K. MORGAN, J. PERAIRE, J. PEIRO (Imperial College of Science, Technology, and Medicine, London, England) et al. AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 16 p. refs

(Contract NAS1-18000; NAS1-19000; NAGW-1809)  
(AIAA PAPER 90-0395)

An upwind cell-centered scheme for the solution of steady laminar viscous high-speed flows is implemented on unstructured two-dimensional meshes. The first-order implementation employs Roe's (1981) approximate Riemann solver, and a higher-order extension is produced by using linear reconstruction with limiting. The procedure is applied to the solution of inviscid subsonic flow over an airfoil, inviscid supersonic flow past a cylinder, and viscous hypersonic flow past a double ellipse. A detailed study is then made of a hypersonic laminar viscous flow on a 24-deg compression corner. It is shown that good agreement is achieved with previous predictions using finite-difference and finite-volume schemes. However, these predictions do not agree with experimental observations. With refinement of the structured grid at the leading edge, good agreement with experimental observations for the distributions of wall pressure, heating rate and skin friction is obtained. Author

**A90-22215#**  
**NUMERICAL SIMULATION OF SUPERSONIC UNSTEADY FLOW USING EULER EQUATIONS**

M. SHU and R. K. AGARWAL (McDonnell Douglas Research Laboratories, Saint Louis, MO) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 17 p. refs  
(AIAA PAPER 90-0415) Copyright

An implicit, upwind, time-accurate Euler solver is being developed to simulate unsteady, two-dimensional supersonic, inviscid, ideal-gas flows. The algorithm employs the alternating direction implicit scheme of Beam and Warming (1977) for time integration of the finite-volume formulation of the unsteady Euler equations. The algorithm is designed for body-conforming grids with generalized boundary-condition specification and multizone capabilities. The algorithm is validated through comparison of solutions to standard, transonic, and supersonic airfoil check cases. Results demonstrate the algorithm's ability to capture complex, unsteady, shock structures accurately, and without oscillation. An entropy-correction model for Roe's (1985) method is discussed also. Author

**A90-22216\*** Vigyan Research Associates, Inc., Hampton, VA.  
**AN EMBEDDED GRID FORMULATION APPLIED TO A DELTA WING**

SHERRIE L. KRIST (Vigyan Research Associates, Inc., Hampton, VA), JAMES L. THOMAS, WILLIAM L. SELLERS, III, and SCOTT O. KJELGAARD (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs

(AIAA PAPER 90-0429) Copyright

Applications using a three-dimensional embedded grid scheme are made to high angle of attack viscous flow over two bodies: a slender cone using the conical approximation and a 75 deg swept delta wing. The embedded grids are used principally to improve

the numerical resolution of the separated vortical flow above the body. Detailed comparisons are made with experimental measurements of the velocity field over the delta wing. The prediction of the maximum steamwise velocity is improved using two levels of embedded grid refinement but is still less than the experimental measurements available from a laser velocimeter.

Author

**A90-22218#**

**AN EULER METHOD FOR WING-BODY-WINGLET FLOWS**

JOHN C. VASSBERG, K. C. CHANG, GARY S. WANG, and KIM YU (Douglas Aircraft Co., Long Beach, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. Research supported by McDonnell Douglas Corp. refs  
(AIAA PAPER 90-0436) Copyright

A method is presented which numerically simulates the transonic flow about wing-body-winglet configurations. The inviscid region of the flowfield is described by the three-dimensional Euler equations numerically discretized by finite-volume as advocated by Jameson et al. (1981), while the viscous shear-layer immediate to the geometry's surface is approximated by the two-dimensional inverse boundary-layer procedure of Cebeci et al. (1985 and 1986). The flowfield grid is body-conforming on all surfaces and is generated using hybrid mapping/numerical procedures. Key advantages of the current grid scheme over previously published work include nearly orthogonal grid lines in the wing-winglet juncture and the ability to treat the important design case of nonmatching wing-to-winglet chord lengths. The present method shows good agreement with Hess's (1980) higher-order surface-panel method for subcritical flow cases; excellent agreement is shown with DC-10 flight data for a range of subcritical to supercritical flow conditions. Author

**A90-22219\*** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**A HYBRID METHOD FOR PREDICTION OF PROPELLER PERFORMANCE**

M. A. TAKALLU (Lockheed Engineering and Sciences Co., Hampton, VA) and D. M. DUNHAM (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs  
(AIAA PAPER 90-0440)

An analytical/computational code has been developed to predict the performance of advanced turboprop propellers. The method of solution is based on strip theory and conservation of linear and angular momenta applied to a control volume enclosing the propeller and its far wake. An iterative procedure is used to account for the induced axial and rotational velocities. Sectional aerodynamic coefficients are explicitly accounted for by thin airfoil theory and refinement of the results is obtained using a two-dimensional vortex panel method and Euler equations. The results obtained compare well with wind-tunnel data obtained for advanced propellers, such as the Hamilton Standard SR-2 and SR-7. Author

**A90-22226#**

**REPRESENTATION OF TWO-DIMENSIONAL HYPERSONIC INLET FLOWS FOR ONE-DIMENSIONAL SCRAMJET CYCLE ANALYSIS**

DAVID WEISSMAN (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 13 p.  
(AIAA PAPER 90-0527)

A generic hypersonic vehicle configuration was modeled at Mach 16 with a dynamic pressure of 1500 psf, to generate a typical scramjet combustor entrance flow profile and demonstrate possible methods of averaging a two-dimensional hypersonic flow profile into a uniform one-dimensional profile. The VSL2D, SCRAMP, and SCRINT two-dimensional parabolized Navier-Stokes codes were used to model the flow about the nose, forebody, and through the inlet of the vehicle. Then, after employing various averaging techniques, the one-dimensional flow representation was interfaced into the Ramjet Performance Analysis code. The possible

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impact of these procedures on the prediction of the scramjet performance is discussed together with the strengths and weaknesses of the averaging methods employed. I.S.

**A90-22230\*#** Analytical Methods, Inc., Redmond, WA.

### **A ZONAL FLOW ANALYSIS METHOD FOR TWO-DIMENSIONAL AIRFOILS**

J. MICHAEL SUMMA, DANIEL J. STRASH, and SUNGYUL YOO (Analytical Methods, Inc., Redmond, WA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p. refs (Contract NAS2-12962) (AIAA PAPER 90-0571) Copyright

A closed-loop, overlapped, velocity-coupling procedure has been utilized to combine a two-dimensional potential flow panel code and a Navier-Stokes code. The fully coupled, two-zone code has been used to compute the flow past a NACA 0012 airfoil. For this case, the zonal method has shown that the grid domain size can be reduced to 0.14 chord lengths with less than 1 percent loss in accuracy. Further, the required computation time is reduced by a factor of approximately four. Author

**A90-22231#**

### **THE INFLUENCE OF SWEEP ON DYNAMIC STALL PRODUCED BY A RAPIDLY PITCHING WING**

KAMBIZ SALARI and PATRICK J. ROACHE (Ecodynamics Research Associates, Inc., Albuquerque, NM) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 37 p. Research supported by USAF. refs (AIAA PAPER 90-0581) Copyright

The influence of sweep on deep dynamic stall of a rapidly pitching swept wing at low Mach number with laminar flow has been investigated through the use of numerical flow simulations. The problem involves the modeling of a wind tunnel test section in which the wing spans the tunnel. The flow Reynolds number is 10,000; the freestream Mach number is 0.2; the reduced frequency is 0.3; and the sweep angle is 30 deg. The solution of the full unsteady three-dimensional compressible Navier-Stokes equations was obtained on the CRAY-2 supercomputer through use of an implicit finite-difference approximate-factorization algorithm coupled with a nonorthogonal moving grid. The sweep effects have been determined by comparing the unswept and swept solutions. Sweep tends to delay the onset of dynamic stall and reduce the magnitude of unsteady aerodynamic loads; however, the intensity of these effects varied significantly along the span of the wing. Author

**A90-22233#**

### **ASYMMETRIC SEPARATED FLOWS AT SUPERSONIC SPEEDS**

M. J. SICLARI (Grumman Research Center, Bethpage, NY) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 15 p. refs (AIAA PAPER 90-0595) Copyright

An efficient multigrid, central difference, finite volume Navier-Stokes solver is used to study the natural occurrence of steady, anomalous, asymmetric separated flow solutions at high incidence and at supersonic speeds. The study documents the regime in which asymmetric conical flows are likely to occur as a function of Mach number and cone angle. It is also shown that the existence of asymmetric flows is not unique to circular cones and is exhibited for a variety of cross sectional shapes. The elimination of asymmetric flow behavior with the addition of strakes is also demonstrated. The paper also presents a parabolized Navier-Stokes solution for a three-dimensional body exhibiting asymmetric flow behavior. Author

**A90-22244#**

### **CONTROLLED THREE-DIMENSIONALITY IN UNSTEADY SEPARATED FLOWS ABOUT A SINUSOIDALLY OSCILLATING FLAT PLATE**

MICHAEL B. HORNER, GREGORY A. ADDINGTON, JAMES W. YOUNG, III, and MARVIN W. LUTTGES (Colorado, University, Boulder) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 13 p. refs

(Contract F49620-84-C-0065)

(AIAA PAPER 90-0689) Copyright

The three-dimensional flow structures which arise from two-dimensional airfoil/wall interactions were investigated using smoke-wire visualization. Significant three-dimensional flows were present in all test conditions where the airfoil was oscillated beyond static stall. Multiple exposure photographs taken along the airfoil span documented the interaction of the three-dimensional end wall flows with the two-dimensional leading edge vortex. The extent of three-dimensionality introduced was directly dependent upon the oscillation parameters and test geometry. The effects of these three-dimensional structures on the two-dimensional flow suggests a simple vortex model may be used to quantify interactions between vortices in unsteady separated flows. Author

**A90-22251#**

### **THE DETECTION OF LARGE SCALE STRUCTURE IN UNDISTURBED AND DISTURBED COMPRESSIBLE TURBULENT FREE SHEAR LAYERS**

D. S. DOLLING (Texas, University, Austin) and Y. R. SHAU AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 13 p.

(AIAA PAPER 90-0711) Copyright

High-frequency response pitot probes were used to make single-point and two-point measurements in a nominally two-dimensional undisturbed and disturbed turbulent shear layer bounded by Mach 3 and Mach 5 streams, with an objective to determine if such measurements can be used to detect and quantify the shear layer large-scale structure. Three cases were studied, including the undisturbed shear layer and two cases in which the initial conditions at the shear-layer origin were changed by planar shock waves impinging on the boundary layer about 6- and 11-boundary-layer thicknesses upstream of the shear-layer origin. Evidence is found of large-scale structures which span the shear layer, with the width and spacing estimated to be about 0.6-0.8 and 1.5-1.8 local shear layer thicknesses, respectively. Differences between the undisturbed and disturbed cases were small. In neither case could a single Strouhal number be defined which would characterize the shear layer dynamics in a meaningful way. I.S.

**A90-22256\*#** Nielsen Engineering and Research, Inc., Mountain View, CA.

### **CHEMICALLY REACTING SUPERSONIC FLOW CALCULATION USING AN ASSUMED PDF MODEL**

M. FARSHCHI (Nielsen Engineering and Research, Inc., Mountain View, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs (Contract NAS3-25633)

(AIAA PAPER 90-0731) Copyright

This work is motivated by the need to develop accurate models for chemically reacting compressible turbulent flow fields that are present in a typical supersonic combustion ramjet (SCRAMJET) engine. In this paper the development of a new assumed probability density function (PDF) reaction model for supersonic turbulent diffusion flames and its implementation into an efficient Navier-Stokes solver are discussed. The application of this model to a supersonic hydrogen-air flame will be considered. Author

**A90-22259#**

### **AN INVESTIGATION OF STRAKE FENCE FLAPS ON A CANARD-CONFIGURED AIRCRAFT**

GREGORY W. PAGE and REBECCA L. SQUIRES AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 8 p.

(AIAA PAPER 90-0762) Copyright

Wind tunnel tests were performed on a canard-configured aircraft to investigate the use of strake fence flaps for improving its landing characteristics. The concept of the strake fence flap is to produce a lift increment due to the formation of a strong vortex over the strake area. The increased lift would allow higher achievable landing lift coefficients and, therefore, lower landing speeds. The increase in drag due to the strake fence flap would also improve deceleration characteristics. This increased drag need

not be detrimental to cruise performance of the aircraft since the strake fence flaps may be retracted onto the surface of the strake. The results of this experiment verified that the trim lift coefficient and the drag could be increased with the deployment of strake fence flaps. Flow visualization also documented the existence and state of the strake fence flap vortices. Author

#### A90-22396

##### COMPARISON OF THIN AND FULL VISCOUS SHOCK LAYER MODELS IN THE PROBLEM OF SUPERSONIC FLOW OF A VISCOUS GAS PAST BLUNT CONES [SRAVNENIE MODELEI TONKOGO I POLNOGO VIAZKOGO UDARNOGO SLOIA V ZADACHE SVERKHZVUKOVOGO OBTEKANIIA PRITUPLENNYKH KONUSOV VIAZKIM GAZOM]

G. A. TIRSKII and S. V. UTIYZHNIKOV Prikladnaia Matematika i Mekhanika (ISSN 0032-8235), vol. 53, Nov.-Dec. 1989, p. 963-969. In Russian. refs

Copyright

Solutions for the equations of a thin (hypersonic) viscous shock layer with a specified shock wave configuration are compared with solutions for the full equations of a viscous layer using supersonic flow of a viscous gas past blunt cones as an example. It is shown that the appropriate specification of the shock wave configuration makes it possible to obtain a solution far downstream and to achieve much better accuracy in comparison with the commonly used asymptotic approach whereby the shock wave configuration is assumed to be equidistant with respect to the body shape. V.L.

#### A90-22421

##### MEAN AND PULSE CHARACTERISTICS OF SUPERSONIC FLOW IN A WIND TUNNEL WITH A HONEYCOMB NOZZLE [OSREDNENNYE PUL'SATSIONNYE KHARAKTERISTIKI SVERKHZVUKOVOGO POTOKA V AERODINAMICHESKOI TRUBE S SOTOVYM SOPLOM]

V. N. ZINOV'EV, M. G. KTALKHERMAN, V. A. LEBIGA, V. M. MAL'KOV, and N. A. RUBAN (AN SSSR, Institut Teoreticheskoi i Prikladnoi Mekhaniki, Novosibirsk, USSR) Akademii Nauk SSSR, Sibirskoe Otdelenie, Izvestiia, Serii Tekhnicheskii Nauki (ISSN 0002-3434), Oct. 1989, p. 37-42. In Russian. refs

Copyright

The mean and pulse characteristics of supersonic flow at the outlet of honeycomb and plane nozzles were determined experimentally under identical conditions in a wind tunnel with a 40x40-mm test section. It is shown that, in the case of a dense honeycomb, sufficiently uniform supersonic flow is achieved, with Mach number variations within + or - 1.5 percent and a mass flow fluctuations of about 2 percent. The results of a parametric analysis of the fully mixed flow characteristics make it possible to select optimum honeycomb geometry for specific conditions. V.L.

#### A90-22422

##### CHARACTERISTICS OF TURBULENT SEPARATION FLOWS ON A POROUS SURFACE UNDER CONDITIONS OF INJECTION [KHARAKTERISTIKI TURBULENTNYKH OTRYVNYKH TECHENII NA PORISTOI POVERKHNOSTI V USLOVIIAKH VDUVA]

A. I. LEONT'EV, V. M. EPIFANOV, A. M. PAVLIUCHENKO, and A. V. PASHUTOV (AN SSSR, Institut Teoreticheskoi i Prikladnoi Mekhaniki, Novosibirsk; Moskovskoe Vysshie Tekhnicheskoe Uchilishche, Moscow, USSR) Akademii Nauk SSSR, Sibirskoe Otdelenie, Izvestiia, Serii Tekhnicheskii Nauki (ISSN 0002-3434), Oct. 1989, p. 50-56. In Russian. refs

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The structure of supersonic turbulent separation flows formed on a flat porous plate in the presence of injection was investigated experimentally in the case of flow around a step and in the case of an oblique external compression shock for Mach up to 3.0 and flow intensities up to 0.3 percent. It is shown that porous injection is an effective method of controlling the dynamic characteristics of supersonic turbulent separation flows. In the presence of injection, the velocity field is deformed to a considerable extent,

the return flow region expands, and the separation zone shifts upstream by up to 25 percent in comparison with the case where injection is absent. V.L.

#### A90-22449\*# Calspan-Buffalo Univ. Research Center, NY. EXPERIMENTAL STUDIES OF SHOCK WAVE/WALL JET INTERACTION IN HYPERSONIC FLOW

MICHAEL S. HOLDEN, KATHLEEN M. RODRIGUEZ (Calspan/UB Research Center, Buffalo, NY), ROBERT NOWAK, and GEORGE OLSEN (NASA, Langley Research Center, Hampton, VA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 19 p. refs

(Contract NAG1-790)

(AIAA PAPER 90-0607)

The interaction between a planar shock wave and a wall jet produced by slot cooling in turbulent hypersonic flow was experimentally studied. Detailed distributions of heat transfer and pressure are obtained in the incident shock/wall jet interaction region for a series of shock strengths and impingement positions for two nozzle heights. The major result is that the cooling film could be readily dispersed by relatively weak incident shocks such that the peak heating in the recompression region was not significantly reduced by even the largest levels of film cooling. Regions of boundary layer separation were induced in the film cooling layer, the size of which first increased and then decreased with increasing film cooling. The size of the separated regions and magnitude of the recompression heating were not strongly influenced by the thickness of the cooling film or point of shock impingement relative to the exit plane of the nozzles. C.D.

#### A90-22668#

##### STABILITY OF FLOW THROUGH MULTISTAGE AXIAL COMPRESSORS

J. P. LONGLEY and T. P. HYNES (Cambridge, University, England) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 112, Jan. 1990, p. 126-132. refs

(ASME PAPER 89-GT-311) Copyright

This paper describes measurements of the performance of a research stage operating in isolation and as part of a multistage compressor. It is shown that the stall point and the stalled performance of the stage are properties of the system in which it operates rather than a property of the stage itself. The consequences of this for the estimation of the stall point for compressors and compression systems are discussed. The support that the measurements give to assumptions made by mathematical models which use the concept of an 'underlying axisymmetric' characteristic, are highlighted. Author

#### A90-22816

##### CONVERGENCE OF THE METHOD OF DISCRETE VORTICES WHEN APPLIED TO STEADY-STATE AERODYNAMICS PROBLEMS [O SKHODIMOSTI METODA DISKRETNYYKH VIKHREI V STATSIONARNYKH ZADACHAKH AERODINAMIKI]

L. N. POLTAVSKI (Voenno-Vozdushnaia Inzhenernaia Akademiia, Moscow, USSR) Akademii Nauk SSSR, Doklady (ISSN 0002-3264), vol. 309, no. 4, 1989, p. 808-811. In Russian. refs

Copyright

The paper demonstrates the convergence of the discrete-vortex method (DVM) in the case of the numerical solution of the integral equation of the theory of nonseparated flow past a finite-span wing. Also provided is the uniform convergence of the approximate solution in the DVM to the exact solution at the ends of the profile, where the vortex-sheet intensity goes to zero. B.J.

#### A90-23036

##### TIME-DEPENDENT AND TIME-AVERAGED TURBULENCE STRUCTURE NEAR THE NOSE OF A WING-BODY JUNCTION

WILLIAM J. DEVENPORT and ROGER L. SIMPSON (Virginia Polytechnic Institute and State University, Blacksburg) Journal of Fluid Mechanics (ISSN 0022-1120), vol. 210, Jan. 1990, p. 23-55. refs

(Contract N60921-83-GA-165B02)

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A three-component laser anemometer has been developed to investigate the behavior of a turbulent boundary layer on a flat surface as it encounters the nose of a cylindrical wing mounted normal to the surface. The data thus obtained are used to estimate some of the component terms of the turbulence kinetic energy equation. Much of the time-dependent and time-averaged turbulence structure of the flow is revealed. The observations presented are consistent with large-scale low-frequency unsteadiness of the instantaneous flow structure associated with the junction vortex. O.C.

**A90-23102#**

### **INDUCED DRAG BASED ON LEADING EDGE SUCTION FOR A HELICOPTER IN FORWARD FLIGHT**

CHENHAO LI, DAVID POLING, and DAVID WU (Boeing Helicopters Co., Philadelphia, PA) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 201-204. refs  
Copyright

Estimating induced drag for a helicopter in forward flight is a three-dimensional, unsteady aerodynamic problem complicated by fluid compressibility and wake geometry. Based on an acceleration potential approach, the chordwise velocity and the derivative of the velocity potential at the leading edge of a thin rotor blade is subsonic flow were re-examined to assess unsteady and compressibility effects on the induced drag using a leading-edge suction model. The chordwise velocity was shown to have a singular and a continuous component. The derivative of the velocity potential was shown to be continuous and hence does not contribute to induced drag. The induced drag calculated from the leading-edge suction model and the more traditional model to be referred to as the induced angle model were compared to quantify the differences in the two approaches. The results show that variations can be significant. While these variations cannot substantiate the validity of either approach, it is clear that the leading edge suction model is simpler to apply with fewer assumptions. Author

**A90-23103\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **NAVIER-STOKES COMPUTATIONS OF VORTICAL FLOWS OVER LOW-ASPECT-RATIO WINGS**

JAMES L. THOMAS, W. KYLE ANDERSON (NASA, Langley Research Center, Hampton, VA), and SHERRIE TAYLOR KRIST (Vigyan Research Associates, Inc., Hampton, VA) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 205-212. Previously cited in issue 08, p. 1035, Accession no. A87-22485. refs  
Copyright

**A90-23105#**

### **AIRFOIL PRESSURE MEASUREMENTS DURING A BLADE VORTEX INTERACTION AND A COMPARISON WITH THEORY**

R. E. MAYLE (Rensselaer Polytechnic Institute, Troy, NY), P. RENZONI (CIRA, Italy), and J. STRAUS AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 222-228. Previously cited in issue 07, p. 940, Accession no. A88-22499. refs  
(Contract DAAG29-92-K-0093)

**A90-23109\*#** Sterling Federal Systems, Inc., Palo Alto, CA.

### **UPWIND DIFFERENCING SCHEME FOR THE TIME-ACCURATE INCOMPRESSIBLE NAVIER-STOKES EQUATIONS**

STUART E. ROGERS (Sterling Federal Systems, Inc., Palo Alto, CA) and DOCHAN KWAK (NASA, Ames Research Center, Moffett Field, CA) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 253-262. Previously cited in issue 16, p. 2596, Accession no. A88-40752. refs  
Copyright

**A90-23124#**

### **ANALYSIS OF TRANSONIC INTEGRAL EQUATIONS. I - ARTIFICIAL VISCOSITY**

W. OGANA (Nairobi, University, Kenya) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 362-364. refs  
Copyright

Artificial viscosity is presently used to solve the two-dimensional integrodifferential and integral equations at nodes located throughout the computational domain. The computation is conducted for nonlifting parabolic-arc and NACA 0012 airfoils. The results obtained compare favorably with finite-difference solutions despite the relatively small number of nodes used, although velocities tend to be higher in such areas of the supersonic zone as just upstream of the shock. O.C.

**A90-23277#**

### **UNSTEADY TRANSONIC AERODYNAMICS OF OSCILLATING AIRFOILS IN SUPERSONIC FREESTREAM**

C. H. WANG, D. K. JAMES, D. D. LIU (Arizona State University, Tempe), and K. Y. FUNG (Arizona, University, Tucson) (Structures, Structural Dynamics and Materials Conference, 28th, Monterey, CA, Apr. 6-8, 1987 and AIAA Dynamics Specialists Conference, Monterey, CA, Apr. 9, 10, 1987, Technical Papers. Part 2A, p. 378-397) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 99-107. Previously cited in issue 14, p. 2102, Accession no. A87-33692. refs  
(Contract N00167-85-K-0164)  
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**A90-23278#**

### **UNSTEADY SUPERSONIC COMPUTATIONS OF ARBITRARY WING-BODY CONFIGURATIONS INCLUDING EXTERNAL STORES**

P. C. CHEN (Zona Technology, Inc., Mesa, AZ) and D. D. LIU (Arizona State University, Tempe) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2, p. 794-812) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 108-116. Previously cited in issue 12, p. 1819, Accession no. A88-32257. refs  
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### **A90-23279\*# Vigyan Research Associates, Inc., Hampton, VA. EFFECTS OF NONPLANAR OUTBOARD WING FORMS ON A WING**

D. A. NAIK (Vigyan, Inc., Hampton, VA) and C. OSTOWARI (Texas A & M University, College Station) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 117-122. Research supported by NASA and Texas A & M University. refs  
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It is possible for a constant span to obtain better aerodynamic performance from a wing with a nonplanar outboard wing form than from a wing with a planar outboard form, despite the added drag from the increased wetted area. Furthermore, the semispan rolling-moment characteristics indicate the lower wing-root bending moment for some nonplanar configurations. These conclusions are based on an experimental and computational investigation of the aerodynamic characteristics of planar and nonplanar outboard wing forms. Seven different configurations - planar rectangular, nonplanar rising arc, nonplanar drooping arc, planar sheared, sheared with dihedral, sheared with anhedral, and planar elliptical - were investigated for two different spans. Flow-visualization photographs indicate that there are three vortex systems associated with the sheared forms. The lower induced drag coefficients of nonplanar wings are believed to accrue from the movement of vorticity away from the center-of-span line, resulting, in some instances, in induced efficiencies higher than that of a planar elliptical wing. Flow surveys indicate that the effective span, as determined by the location of the tip vortex, might not be a sufficient yardstick of the induced performance of a nonplanar wing.

Author

**A90-23280\*#** Old Dominion Univ., Norfolk, VA.

### **INTEGRAL SOLUTION OF UNSTEADY FULL-POTENTIAL EQUATION FOR A TRANSONIC PITCHING AIRFOIL**

OSAMA A. KANDIL and HONG HU (Old Dominion University, Norfolk, VA) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 123-130. refs  
(Contract NAG1-648)  
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The unsteady full-potential equation formulation in a moving frame of reference has been developed and used to solve unsteady transonic flow problems. An unsteady integral-equation shock-capturing (IE-SC) scheme has been developed. The resulting unsteady IE-SC scheme is applied to a NACA 0012 airfoil undergoing a pitching oscillation. The numerical results are compared with those of an implicit, approximately factored, finite-volume Euler scheme. The present scheme is efficient in terms of the number of iterations as compared to the other existing schemes, which use finite-difference or finite-volume methods.

Author

**A90-23281\*#** Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.

#### **VORTEX DYNAMICS ON A PITCHING DELTA WING**

S. P. LEMAY (USAF, Wright Research and Development Center, Wright-Patterson AFB, OH), S. M. BATILL, and R. C. NELSON (Notre Dame, University, IN) *Journal of Aircraft* (ISSN 0021-8669), vol. 27, Feb. 1990, p. 131-138. Research supported by University of Notre Dame. Previously cited in issue 16, p. 2594, Accession no. A88-40735. refs  
(Contract NAG1-727)  
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**A90-23283#**

#### **FLIGHT AND WIND-TUNNEL INVESTIGATIONS ON BOUNDARY-LAYER TRANSITION**

K. H. HORSTMANN, A. QUAST, and G. REDEKER (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) (ICAS, Congress, 16th, Jerusalem, Israel, Aug. 28-Sept. 2, 1988, Proceedings. Volume 2, p. 979-986) *Journal of Aircraft* (ISSN 0021-8669), vol. 27, Feb. 1990, p. 146-150. Previously cited in issue 03, p. 259, Accession no. A89-13601. refs  
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**A90-23285\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

#### **LEADING- AND TRAILING-EDGE FLAPS ON SUPERSONIC DELTA WINGS**

GLORIA HERNANDEZ, RICHARD M. WOOD (NASA, Langley Research Center, Hampton, VA), and ROBERT E. COLLINS (Planning Research Corp., Hampton, VA) *Journal of Aircraft* (ISSN 0021-8669), vol. 27, Feb. 1990, p. 158-162. Previously cited in issue 09, p. 1270, Accession no. A89-25023. refs  
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**A90-23289\*#** Vigyan Research Associates, Inc., Hampton, VA.  
**STUDY OF VORTEX BREAKDOWN OF F-106B BY EULER CODE**

JENN LOUH PAO (Vigyan Research Associates, Hampton, VA) *Journal of Aircraft* (ISSN 0021-8669), vol. 27, Feb. 1990, p. 185-187. refs  
(Contract NAS1-17919).  
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The 'Three-dimensional Euler Aerodynamic Method' (TEAM) is presently applied to the F-106B at subsonic speed, in order to examine the relationship between off- and on-surface flow features at angles-of-attack sufficiently great for the occurrence of vortex breakdown. Although TEAM's flow separation is triggered by numerical dissipation, the general trend of vortex-breakdown effect on computed lift characteristics is similar to extant wind tunnel results.

O.C.

**A90-23290#**

#### **INCOMPRESSIBLE VISCOUS FLOW ABOUT AIRCRAFT CONFIGURATIONS**

K. P. SINHAMAHAPATRA, N. SINGH, and B. C. BASU (Indian Institute of Technology, Kharagpur, India) *Journal of Aircraft* (ISSN 0021-8669), vol. 27, Feb. 1990, p. 187-190. Research supported by the Aeronautical Research and Development Board. refs

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An internal singularity distribution is used for the lifting

components in the present, highly economical viscous panel method, in order to calculate the attached flow past a given aircraft configuration. Satisfactory results are thus obtained with a number of panels which is significantly lower than a surface singularity method. While the modeling of the interference is rudimentary, the results obtained are suitable for numerous engineering applications.

O.C.

**A90-23291#**

#### **COMMENT ON 'INDUCED DRAG AND THE IDEAL WAKE OF A LIFTING WING'**

W. R. SEARS (Arizona, University, Tucson) *Journal of Aircraft* (ISSN 0021-8669), vol. 27, Feb. 1990, p. 191; Author's Reply, p. 191, 192. refs  
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**A90-23355**

#### **MEASUREMENTS AND CALCULATIONS OF THE AERODYNAMIC CHARACTERISTICS OF THE PROPELLER SECTIONS SERIES V3 [MERENI A VYPOCTY AERODYNAMICKYCH CHARAKTERISTIK VRTULOVYCH PROFILURADY V3]**

JIRI BENETKA and JAN DOSTAL *Zpravodaj VZLU* (ISSN 0044-5355), no. 5, 1989, p. 261-266. In Czech. refs  
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A new two-dimensional transonic test section of dimensions 0.4 m x 0.8 m has been introduced into operation in the high-speed aerodynamic laboratory of the ARTI. The first measurements were performed with the propeller sections series V3, possessing supercritical properties. Calculations of the aerodynamic characteristics of this section series were performed, using the SWSH code. A comparison of measured and calculated characteristics was carried out.

Author

**A90-23356**

#### **UNCONVENTIONAL LEADING EDGES OF AIRFOILS [NETRADICNI NABEZNE HRANY PROFILU]**

PETR BERAK *Zpravodaj VZLU* (ISSN 0044-5355), no. 5, 1989, p. 267-272. In Czech. refs  
Copyright

Calculations based on the inverse method were used to obtain a series of symmetric profiles with unconventional rounded leading edges. In the case of symmetric flow, pressure-distribution waves are not generated on them, similar to the case of a parabolic leading edge. The results obtained constitute a contribution to increasing the maximum lift capabilities of airfoil sections and of the efficiency of flaps by reducing pressure peaks on the leading edges.

B.J.

**A90-23361**

#### **AERODYNAMIC CHARACTERISTICS OF AN AIRCRAFT MODEL AT LARGE ANGLES OF ATTACK AND LARGE SIDESLIP [AERODYNAMICKE CHARAKTERISTIKY MODELU LETOUNU PRI VYSOKYCH UHLECH NABEHU A VYBOCENI]**

ZDENEK PATEK *Zpravodaj VZLU* (ISSN 0044-5355), no. 5, 1989, p. 291-294. In Czech.  
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The basic aerodynamic characteristics of an aircraft model at large angles of attack and sideslip angles were investigated in a wind tunnel. The model was of a conventional configuration with an unswept wing. In addition to changes of lift and drag coefficients, the characteristics of stability and maneuverability vary significantly. It is emphasized that a high level of engine thrust is necessary for the efficient use of high angles of attack and high sideslip angles, and that the problems of variations of stability and maneuverability must be solved.

Author

**A90-23362**

#### **NUMERICAL METHOD FOR THE FLOW OF AN IDEAL FLUID ON A PLANE WITH SUBSONIC AND SUPERSONIC REGIONS [NUMERICKA METODA PRO PROUDENI IDEALNIHO PLYNU V ROVINE S PODZVUKOVYMI A NADZVUKOVYMI OBLASTMI]**



JAROSLAV PELANT Zpravodaj VZLU (ISSN 0044-5355), no. 5, 1989, p. 295, 296. In Czech.  
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The paper describes a numerical method for the flow of an ideal fluid on a plane using equations rewritten into the integral form. The validity of the matter, energy, and momentum conservation laws is assumed. The integral form admits of discontinuities in velocity, pressure, and density. The method can neglect the prior definition of the subsonic and supersonic regions and it is based on the decay of the discontinuities of gasdynamic quantities on the grid covering the region considered. Author

**A90-23401**

**SELECTION OF THE BLENDED WING CONFIGURATION FOR LIGHT AIRCRAFT [VYBOR FORMY SOSTAVNOGO KRYLA DLIA LEGKOGO SAMOLETA]**

A. A. BADIAGIN Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1989, p. 3-5. In Russian.  
Copyright

The paper is concerned with the problem of selecting the optimum planform of a blended wing/fuselage for. In particular, an optimization procedure is presented for the ratio of the cantilever and lifting body areas. The efficiency of a lifting body of tapered planform is demonstrated with reference to the results of calculations for a specific case. V.L.

**A90-23422**

**AN APPROXIMATE METHOD FOR CALCULATING FLOW PAST A WING PROFILE WITH ALLOWANCE FOR VISCOSITY [PRIBLIZHENNYI METOD RASCHETA OBTEKANIIA PROFILIA KRYLA S UCHETOM VIAZKOSTI]**

Z. KH. NUGMANOV and V. A. OVCHINNIKOV Aviatsionnaia Tekhnika (ISSN 0579-2975), no. 4, 1989, p. 81-83. In Russian.  
refs  
Copyright

A simple method is proposed for calculating flow of a viscous incompressible fluid past an airfoil at large Reynolds numbers. The effect of viscosity is taken into account by using a correction of the angle of attack based on experimental data. Velocity distribution is determined from perfect fluid theory when the boundary condition is satisfied at a given contour. The boundary layer parameters are calculated by integral methods. V.L.

**A90-23432**

**TRANSFER OF THE ATOMIC ION ENERGY OF SUPERSONIC FLOW OF A PARTIALLY DISSOCIATED GAS TO A SOLID SURFACE [O PEREDACHE ENERGII ATOMARNYKH IONOV SVERKHZVUKOVOGO POTOKA CHASTICHNO DISSOTSIIROVANNOGO GAZA POVERKHNOSTI TVERDOGO TELA]**

N. P. REZNICHENKO and V. A. SHUVALOV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki (ISSN 0044-4626), Nov.-Dec. 1989, p. 11-19. In Russian. refs  
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Results of experimental studies of energy transfer between the atomic ions of supersonic gas flows and solid surfaces are reported. A method for determining recombination coefficients is proposed, and recombination coefficients are determined for the atomic ions of nitrogen, hydrogen, and oxygen on the surface of polycrystalline electrically conducting materials and alloys (e.g., Mo, Pt, Cu, Al, Ag, and steels 25 and 12Kh18N10T). Measurements of the transmission coefficients of different surfaces are presented. V.L.

**A90-23435**

**A STUDY OF FLOW OF A VIBRATIONALLY NONEQUILIBRIUM DISSOCIATED GAS PAST A BLUNT BODY [ISSLEDOVANIE OBTEKANIIA ZATUPLENNOGO TELA KOLEBATEL'NO-NERAVNOVESNYM DISSOTSIIROVANNYM GAZOM]**

O. IU. APOLONSKII, P. E. BABIKOV, I. V. LEBED', and V. V. RIABOV PMTF - Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi

Fiziki (ISSN 0044-4626), Nov.-Dec. 1989, p. 139-145. In Russian.  
refs

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The problem of flow of a vibrationally nonequilibrium dissociated gas past a blunt body is solved using the CVDV model (Marrone and Treanor, 1963), which allows for the relation between dissociation and vibrations. Particular attention is given to the analysis of the effect of dissociation processes and vibrational nonequilibrium on the thermal loading of a flight vehicle. Calculation results are presented for supersonic flow of a dissociated gas (oxygen or nitrogen) past a sphere. V.L.

**A90-23647\*** # National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**TURBULENCE MODELING FOR AERODYNAMIC FLOWS**

MORRIS W. RUBESIN (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 43 p. refs  
(AIAA PAPER 89-0606) Copyright

The state of statistical turbulence modeling is reviewed with emphasis on compressible aerodynamic flows. A three-stage modeling process is suggested to act as a frame-work for improving turbulence models for complex flows. This process is then used to guide assessments of the comparative performance of various levels of turbulence models for several examples of flow fields of aerodynamic interest. The examples cover flows in two and three dimensions and with a broad range of Mach numbers. In addition to considerations of individual flow fields, some generalizations are drawn from the aggregate behavior of the comparisons.

Author

**A90-23650\*** # National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**EFFECT OF REDUCED AFT DIAMETER AND INCREASED BLADE NUMBER OF HIGH-SPEED COUNTERROTATION PROPELLER PERFORMANCE**

E. ROSE GAYLE and ROBERT J. JERACKI (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 27th, Reno, NV, Jan. 9-12, 1989. 32 p. Previously announced in STAR as N90-13352. refs  
(AIAA PAPER 89-0438)

Performance data of 0.17-scale model counterrotation pusher propeller configurations were taken in the NASA Lewis 8- by 6-Foot Supersonic Wind Tunnel at Mach numbers of 0.66, 0.71, 0.75, and 0.79. These tests investigated the aerodynamic performance of the unducted fan (UDF) demonstrator propeller engine developed in a joint program by General Electric and NASA. Data were recorded to show the effect on counterrotation propeller cruise efficiency of two takeoff noise-reduction concepts. These two concepts are reduced aft blade diameter and increased forward blade number. The four configurations tested were a baseline (F1/A1 8/8) configuration, a reduced aft diameter (F1/A3 8/8) configuration, an increase forward blade number (F1/A1 9/8) configuration, and a combination of the latter two (F1/A3 9/8) configurations. Data were collected with a complex counterrotation propeller test rig via rotating thrust and torque balances and pressure instrumentation. Data comparisons documented the power differences between the baseline and the reduced aft diameter concepts. Performance comparisons to the baseline configuration showed that reducing the aft blade diameter reduced the net efficiency, and adding a blade to the front rotor increased the net efficiency. The combination of the two concepts showed only slightly lower net efficiency than the baseline configuration. It was also found that the counterrotation demonstrator propeller model (F7/A7 8/8) configuration outperformed the baseline (F1/A1 8/8) configuration. Author

**A90-23701\*** # Virginia Polytechnic Inst. and State Univ., Blacksburg.

**A THREE-DIMENSIONAL SPACE MARCHING ALGORITHM FOR THE SOLUTION OF THE EULER EQUATIONS ON UNSTRUCTURED GRIDS**

W. D. MCGRORY (Walters Software, Inc., Blacksburg, VA), R. W.

WALTERS (Virginia Polytechnic Institute and State University, Blacksburg), and R. LOHNER (George Washington University, Washington, DC) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 10 p. refs  
(Contract NSF ISI-88-61052; NAG1-776)  
(AIAA PAPER 90-0014) Copyright

A three-dimensional space marching algorithm using an unstructured discretization is proposed. The governing equations and the spatial discretization of the domain and the interpolation from one arbitrary unstructured mesh to another are discussed, and the grid generation technique is described. Solutions for several different geometries are presented, and the results are compared with existing numerical techniques and experimental results.

C.D.

**N90-15064#** Boeing Commercial Airplane Co., Renton, WA. Configuration and Certification Group.

**FLIGHT AND WIND TUNNEL INVESTIGATION OF AERODYNAMIC EFFECTS OF AIRCRAFT GROUND DEICING/ANTIICING FLUIDS**

L. JAMES RUNYAN, THOMAS A. ZIERTEN, and EUGENE G. HILL /n AGARD, Flight in Adverse Environmental Conditions 11 p Sep. 1989

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A flight and wind tunnel investigation of the effects of aircraft ground deicing/anti-icing fluids on the aerodynamic characteristics of a Boeing 737-200ADV airplane was conducted. The flight test was performed in Kuopio, Finland, and the wind tunnel test was carried out in the NASA Lewis Research Center Icing Research Tunnel. Fluids tested in both flight and the wind tunnel include a newtonian deicing fluid and three nonnewtonian anti-icing fluids commercially available during or prior to 1988. Both the flight test results and the wind tunnel results show that fluids remain on the wing after liftoff and cause a measurable lift loss and drag increase. Eight newly developed nonnewtonian fluids, tested only in the wind tunnel, show significantly improved aerodynamic characteristics relative to the existing nonnewtonian fluids that were tested. Wind tunnel results also indicate that the fluid effects are configuration dependent. For a configuration with deflected leading edge high-lift devices, the fluid effect is largest at the maximum lift condition. For a configuration without leading edge high-lift devices, the fluid effect is very small at the maximum lift condition. It was also found that the fluid aerodynamic effects are related to the fluid surface roughness, particularly in the first 30 percent chord.

Author

**N90-15069** Mississippi State Univ., State College.  
**UNSTEADY THREE-DIMENSIONAL THIN-LAYER NAVIER-STOKES SOLUTIONS ON DYNAMIC BLOCKED GRIDS Ph.D. Thesis**

BRUCE SIMPSON 1988 164 p  
Avail: Univ. Microfilms Order No. DA8909503

An efficient scheme for calculating steady and unsteady solutions on blocked grids for several airfoils and wings is presented. Two algorithms are presented, both of which are based on upwind, finite-volume, flux splitting for the convective terms, and an explicit treatment of the diffusive terms. The first algorithm is based on a flux-vector split (FVS) scheme while the second algorithm is based on a flux-difference split (FDS) scheme. The two algorithms are compared for steady thin-layer Navier-Stokes solutions on a laminar flat plate, RAE 2822 airfoil, and the ONERA M6 wing. The FDS scheme proved to be superior to the FVS in all cases, due to the excessive numerical dissipation in the FVS scheme. A flat plate laminar boundary layer profile is shown with the FDS scheme correctly modeling the boundary layer (compared to a Blasius solution) with only three grid cells internal to the boundary layer. The FVS scheme was not capable of correctly modeling the boundary layer profile. The FDS algorithm was used to evaluate the scheme for unsteady viscous calculations. The diffusive terms are time-lagged in the solution process and therefore are treated as source terms to the convective terms, which behave

as a hyperbolic set of equations. The scheme is second order accurate in space and first order accurate in time due to the explicit treatment of the diffusive terms. A Newton subiteration technique was implemented to allow for larger time step sizes and second order temporal accuracy. Dissert. Abstr.

**N90-15070** Princeton Univ., NJ.  
**NONLINEAR PHENOMENA IN COMPUTATIONAL TRANSONIC AEROELASTICITY Ph.D. Thesis**

KENNETH ARTHUR KOUSEN 1989 154 p  
Avail: Univ. Microfilms Order No. DA8908052

An unsteady Euler equation solver was coupled to a typical section airfoil containing pitching and plunging degrees of freedom. A new structural integrator was implemented based on a convolution integral solution of the second order equations of motion for the normal modes of the structure. The aerodynamic model consisted of a finite volume discretization of the unsteady Euler equations, which were integrated with a five-stage Runge-Kutta scheme using artificial dissipation in the first two stages. After coupling the two numerical models together, the combined system was integrated forward in time. Flutter oscillations in the transonic regime fell into a series of limit cycles that generally made up supercritical bifurcations. A weak divergence behavior was also observed, characterized by the slow progression of the system towards finite, nonzero equilibria. For this same system at higher reduced velocities, interactions between the static instability of divergence and the dynamic instability of flutter were demonstrated. A standard two dimensional model for a section of a swept wing was also analyzed. The flutter curve in this case exhibited the transonic dip phenomenon, and the present code verified the existence of multiple flutter points in the transonic range. These multiple points were then seen to be the boundaries of stability regions composed of limit cycle oscillations for the two different flutter modes of the coupled system. Dissert. Abstr.

**N90-15072\*#** Texas A&M Univ., College Station. Dept. of Aerospace Engineering.

**A DIRECT-INVERSE METHOD FOR TRANSONIC AND SEPARATED FLOWS ABOUT AIRFOILS Final Report**

LELAND A. CARLSON Washington Jan. 1990 72 p  
(Contract NSG-1174)

(NASA-CR-4270; NAS 1.26:4270; TAMRF-3224-85-12) Avail: NTIS HC A04/MF A01 CSDL 01A

A direct-inverse technique and computer program called TAMSEP that can be used for the analysis of the flow about airfoils at subsonic and low transonic freestream velocities is presented. The method is based upon a direct-inverse nonconservative full potential inviscid method, a Thwaites laminar boundary layer technique, and the Barnwell turbulent momentum integral scheme; and it is formulated using Cartesian coordinates. Since the method utilizes inverse boundary conditions in regions of separated flow, it is suitable for predicting the flow field about airfoils having trailing edge separated flow under high lift conditions. Comparisons with experimental data indicate that the method should be a useful tool for applied aerodynamic analyses.

Author

**N90-15074** Georgia Inst. of Tech., Atlanta.  
**UNSTEADY AERODYNAMICS OF OSCILLATING AND RAPIDLY PITCHED AIRFOILS Ph.D. Thesis**

ISMAIL HAKKI TUNCER 1988 221 p  
Avail: Univ. Microfilms Order No. DA8916174

A theoretical method and a computational method are developed and calibrated for the routine and accurate prediction of unsteady aerodynamic forces acting on lifting bodies. These methods are employed to produce improved understanding of the dynamic stall phenomena experienced by large amplitude rapidly pitched or oscillating airfoils. The analysis is based on the unsteady, incompressible, two-dimensional Navier-Stokes equations expressed in terms of velocity and vorticity vectors. The turbulence in high Reynolds number flows is simulated by the Baldwin-Lomax model. The governing differential equations are cast into an integro-differential formulation, which consists of the vorticity

transport equation and the integral representation for velocity. This formulation confines the solution domain only to the viscous zone of the flow excluding the potential flow zone and leads to an efficient zonal solution procedure. In the theoretical study, the diffusion of vorticity is neglected. The flow field is represented by a thin surface vortex sheet around the airfoil and concentrated vortex filaments in the wake. Computational demands are greatly reduced by the partial analytic evaluations. In the viscous flow analysis, the vorticity transport equation is discretized on an O-grid around the airfoil. In solving the integral equation for velocity, finite Fourier series are utilized. Unsteady flow fields around rapidly pitched and oscillating airfoils and dynamic stall phenomena are simulated. The predicted flow fields are presented by instantaneous streamlines, vorticity contours and surface pressure distribution curves along the unsteady airfoil motion. The aerodynamic load hystereses are given. The NACA-0012 and SC-1095 airfoils are studied for different reduced pitching rate and reduced frequency motions. The formation and downstream convection of the leading edge vortex and its strong relationship to the dynamic stall phenomenon are assessed. Numerical predictions agree well with experimental data. Dissert. Abstr.

**N90-15075** Georgia Inst. of Tech., Atlanta.  
**FINITE DIFFERENCE TECHNIQUES AND ROTOR BLADE AEROELASTIC PARTIAL DIFFERENTIAL EQUATIONS WITH QUASISTEADY AERODYNAMICS** Ph.D. Thesis  
 YILDIRIM KEMAL YILLIKCI 1988 181 p  
 Avail: Univ. Microfilms Order No. DA8916177

A conditionally stable explicit finite difference scheme is used to numerically integrate the nonlinear partial differential equation of motion in space and time to obtain the aeroelastic steady-state and transient responses of a rotor blade. Numerical stability analyses are performed for different blade parameters, flight conditions and spatial discretizations. The effects of different spatial discretizations on blade response and the convergence of the finite difference scheme are also analyzed. Rotor blade responses are calculated for different blade configurations and flight conditions and results are presented and compared with the results of previous analyses. Finally, different aspects of using computational rotor blade aerodynamics in response calculations and one period solution formulation by the use of finite difference equations are discussed without numerical results. Dissert. Abstr.

**N90-15076#** Sandia National Labs., Albuquerque, NM. Parachute System Div.  
**AN EXPERIMENTAL INVESTIGATION OF WALL-INTERFERENCE EFFECTS FOR PARACHUTES IN CLOSED WIND TUNNELS**

J. MICHAEL MACHA and ROBERT J. BUFFINGTON Sep. 1989 25 p  
 (Contract DE-AC04-76DP-00789)  
 (DE90-001802; SAND-89-1485) Avail: NTIS HC A03/MF A01

A set of 6-ft-diameter ribbon parachutes (geometric porosities of 7, 15, and 30 percent) was tested in various subsonic wind tunnels covering a range of geometric blockages from 2 to 35 percent. Drag, base pressure, and inflated geometry were measured under full-open, steady-flow conditions. The resulting drag areas and pressure coefficients were correlated with the bluff-body blockage parameter (i.e., drag area divided by tunnel cross-sectional area) according to the blockage theory of Maskell. The data show that the Maskell theory provides a simple, accurate correction for the effective increase in dynamic pressure caused by wall constraint for both single parachutes and clusters. For single parachutes, the empirically derived blockage factor  $K(\text{sub } M)$  has the value of 1.85, independent of canopy porosity. Derived values of  $K(\text{sub } M)$  for two- and three-parachute clusters are 1.35 and 1.59, respectively. Based on the photometric data, there was no deformation of the inflated shape of the single parachutes up to a geometric blockage of 22 percent. In the case of the three-parachute cluster, decreases in both the inflated diameter and the spacing among member parachutes were observed at a geometric blockage of 35 percent. DOE

**N90-15079#** Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.

**AN ALTERNATIVE DERIVATION FOR AN INTEGRAL EQUATION FOR LINEARIZED SUBSONIC FLOW OVER A WING** Final Report, Feb. 1988 - Jan. 1989

MARC H. WILLIAMS, KARL G. GUDERLEY, and MARK R. LEE  
 Aug. 1989 41 p  
 (AD-A214140; WRDC-TR-89-3097) Avail: NTIS HC A03/MF A01 CSCL 01/1

An integral equation for the time dependent linearized subsonic flow over a wing has been derived in a previous report by K. G. Guderley and Maxwell Blair (AD-A176684). The present alternative derivation due to Marc H. Williams is presented. The difference lies in the sequence of events. The original derivation was carried out in a coordinate system moving with the wing. Williams' derivation makes the crucial step in a coordinate fixed in the undisturbed air and then carries out a transformation to wing coordinates. In addition, this derivation clarifies the relation between the integral equation for steady and unsteady flow, and derives a formulation based on the Lorentz transform. GRA

**N90-15080#** Naval Postgraduate School, Monterey, CA. Dept. of Aeronautics and Astronautics.

**FLOW VISUALIZATION OF THE EFFECT OF PITCH RATE ON THE VORTEX DEVELOPMENT ON THE SCALE MODEL OF A F-18 FIGHTER AIRCRAFT** M.S. Thesis

SUNG-NAM PARK Jun. 1989 145 p Sponsored in part by Naval Air Systems Command  
 (AD-A214244) Avail: NTIS HC A07/MF A01 CSCL 01/1

Experiments were performed in a water tunnel to visualize the vortex bursting phenomenon on a 1/48th scale model of the F-18 fighter aircraft. Photographs were taken to investigate the effect of pitch rate and yawing on bursting locations of vortices shed from the forebody and the strake during simple pitch up and simple pitch down maneuvers in an angle of attack range up to 50 degrees. It was found that the vortex burst point moves upstream with increasing pitch rate. At the same pitch rate, vortex bursting was usually found to occur earlier for the pitch-down than for the pitch-up maneuver. Aircraft yawing generated significant vortex asymmetries due to earlier vortex bursting on the windward side thus leading to undesirable side forces. GRA

**N90-15081** ESDU International Ltd., London (England).  
**INSTALLED TAILPLANE LIFT-CURVE SLOPE AT SUBSONIC SPEEDS**

Oct. 1989 17 p  
 (ESDU-89029; ISBN-0-85679-701-4; ISSN-0141-397X) Avail: ESDU

ESDU 89029 provides a simple semi-empirical correlation of experimental data from the literature for installed tailplane efficiency for both fin- and body-mounted cases. Efficiency here is installed lift-curve slope normalized by the theoretical free-air value, in this case as predicted by ESDU 70011. The correlation yields two graphs, one for each case, of efficiency against the most appropriate geometric parameter characterizing the airframe interference. Subcritical Mach number effects are accounted for by use of the compressible lift-curve slope from ESDU 70011 but it was found that some improvement in correlation could be achieved by an additional correction factor. The methods apply to cases with or without high-lift devices deployed. Except for fin-mounted tailplanes on close-coupled configurations, the methods will predict lift-curve slope to within 6 percent for any straight-tapered tailplane, as is shown by a sketch of predicted against experimental results for some 70 cases. Two detailed examples illustrate the use of the methods. The techniques used to extract the installed lift-curve slope from the wind-tunnel data are detailed. ESDU

**N90-15082** ESDU International Ltd., London (England).  
**THE MAXIMUM LIFT COEFFICIENT OF PLAIN WINGS AT SUBSONIC SPEEDS**

Oct. 1989 24 p

(ESDU-89034; ISBN-0-85679-707-3; ISSN-0141-397X) Avail: ESDU

ESDU 89034 gives an empirical method for estimating the maximum lift of aerodynamically smooth straight-tapered wings with or without camber and/or twist but with high lift devices undeflected. Any shape of section or camber line, both of which may vary spanwise, can be treated. Linear spanwise variation of combined twist (geometric and camber-induced) is assumed, but by means of an equivalent linear twist it can also be applied to wings with non-linear monotonic twist. It can also be applied to wings with cranked or curved edges by use of the equivalent straight-tapered wing concept of ESDU 76003. The method uses the approach of ESDU 83040 for an unswept, untwisted wing to locate the most highly loaded section. ESDU 84026 is used to find the maximum lift there which is then related to the wing overall lift. Corrections are applied as appropriate for sweep and twist effects and for the influence of Mach and Reynolds numbers. The method has been tested against wing alone wind-tunnel data (including half models) extracted from the literature for a range of wing geometries (aspect ratio 2 to 12, sweeps up to 50 degrees, taper ratios 0.2 to 1.0) for Mach numbers to 0.8, and was found generally to predict the maximum lift coefficient to within 10 percent. ESDU

**N90-15882\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**ROTOR INDUCED-INFLOW-RATIO MEASUREMENTS AND CAMRAD CALCULATIONS**

DANNY R. HOAD Washington Jan. 1990 28 p Original contains color illustrations  
(Contract DA PROJ. 1L1-62211-A-47-AA)  
(NASA-TP-2946; L-16594; NAS 1.60:2946;  
AVSCOM-TM-89-B-010) Avail: NTIS HC A03/MF A01 CSDL 01/1

Comparison of the inflow calculations between an analytical rotor wake method and rotor inflow measurements using a laser velocimeter was presented. The inflow measurements were made near a 4-bladed rotor system using rectangular planform blades operating in forward flight at a thrust coefficient of 0.0064, and at 3 rotor advance ratios: 0.15, 0.23, and 0.30. The inflow measurements were made at azimuthal increments of 30 degrees at 3.0 inches (approximately 1 chord) above the plane formed by the tips of the blades, and radial locations from 20 to 110 percent of blade span. The experimental measurements showed that as the advance ratio ( $m$ ) increased, the induced upflow region moved progressively from the forward 20 percent of the rotor disc at  $m = 0.15$  to covering most of the forward half of the rotor disc at  $m = 0.30$ . The induced inflow characteristics at all advance ratios were found to be unsymmetrical about the longitudinal centerline. The maximum downwash was found to be in the rear portion of the disc and skewed toward the advancing blade side. The comparisons with the analytical method Comprehensive Analytical Model of Rotorcraft Aerodynamics and Dynamics (CAMRAD) show that the region of induced upflow over the rotor disc was effectively modeled only at the advance ratio of 0.15. The method consistently indicated the largest values of induced inflow ratio to be on the retreating-blade side of the rotor disc (opposite from that measured). The importance of the choice of rotor trim option is examined and results of two trim selections are detailed. Author

**N90-15884\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**AN EXPERIMENTAL INVESTIGATION OF THRUST VECTORING TWO-DIMENSIONAL CONVERGENT-DIVERGENT NOZZLES INSTALLED IN A TWIN-ENGINE FIGHTER MODEL AT HIGH ANGLES OF ATTACK**

FRANCIS J. CAPONE, MARY L. MASON, and LAURENCE D. LEAVITT Washington Feb. 1990 123 p  
(NASA-TM-4155; L-16563; NAS 1.15:4155) Avail: NTIS HC A06/MF A01 CSDL 01/1

An investigation was conducted in the Langley 16-Foot Transonic Tunnel to determine thrust vectoring capability of subscale 2-D convergent-divergent exhaust nozzles installed on a twin engine general research fighter model. Pitch thrust vectoring

was accomplished by downward rotation of nozzle upper and lower flaps. The effects of nozzle sidewall cutback were studied for both unvectored and pitch vectored nozzles. A single cutback sidewall was employed for yaw thrust vectoring. This investigation was conducted at Mach numbers ranging from 0 to 1.20 and at angles of attack from -2 to 35 deg. High pressure air was used to simulate jet exhaust and provide values of nozzle pressure ratio up to 9. Author

**N90-15886\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**ASSESSMENT OF COMPUTATIONAL PREDICTION OF TAIL BUFFETING**

JOHN W. EDWARDS Jan. 1990 42 p  
(NASA-TM-101613; NAS 1.15:101613) Avail: NTIS HC A03/MF A01 CSDL 01/1

Assessments of the viability of computational methods and the computer resource requirements for the prediction of tail buffeting are made. Issues involved in the use of Euler and Navier-Stokes equations in modeling vortex-dominated and buffet flows are discussed and the requirement for sufficient grid density to allow accurate, converged calculations is stressed. Areas in need of basic fluid dynamics research are highlighted: vorticity convection, vortex breakdown, dynamic turbulence modeling for free shear layers, unsteady flow separation for moderately swept, rounded leading-edge wings, vortex flows about wings at high subsonic speeds. An estimate of the computer run time for a buffeting response calculation for a full span F-15 aircraft indicates that an improvement in computer and/or algorithm efficiency of three orders of magnitude is needed to enable routine use of such methods. Attention is also drawn to significant uncertainties in the estimates, in particular with regard to nonlinearities contained within the modeling and the question of the repeatability or randomness of buffeting response. Author

**N90-15889#** European Space Agency, Paris (France).

**WIND TUNNEL TESTS OF THE INFLUENCE OF AEROFOIL THICKNESS ON THE NORMAL FORCE AND PITCHING MOMENT OF TWO SLENDER WINGS AT TRANSONIC AND SUPERSONIC MACH NUMBERS**

HELMUT ESCH (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Cologne, Germany, F.R. ) Aug. 1989 190 p. Transl. into ENGLISH of Windkanalmessungen zum Einfluss der Profildicke von zwei Geometrisch Einfachen, Schlanken Fluegeln im Trans- und Uberschallgeschwindigkeitsbereich  
Original language document was announced as N88-27171  
(ESA-TT-1129; DFVLR-FB-88-17; ETN-90-96189) Avail: NTIS HC A09/MF A02; original German report available from DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Federal Republic of Germany, 67.50 deutsche marks

Forces at subsonic, transonic, and supersonic Mach numbers are measured. The investigation is performed in order to determine the influence of aerofoil thickness and shape on the normal force and pitching moment of slender wings. Both wings, a rectangular and a clipped delta wing, had hexagonal wing sections. The wing thickness, the edge angle and edge radius are varied. The tests are carried out in a trisonic wind tunnel at Mach numbers between 0.5 and 4. In supersonic flow, the incidence varied between -10 deg and 90 deg. ESA

**N90-15891\*#** Old Dominion Univ., Norfolk, VA. Dept. of Mechanical Engineering and Mechanics.

**APPLICATION OF LAGRANGIAN BLENDING FUNCTIONS FOR GRID GENERATION AROUND AIRPLANE GEOMETRIES Final Report, period ended 30 Sep. 1989**

JAMSHID S. ABOLHASSANI, IDEEN SADREHAGHIGHI, and SURENDRA N. TIWARI Feb. 1990 29 p  
(Contract NAS1-18584)  
(NASA-CR-186318; NAS 1.26:186318) Avail: NTIS HC A03/MF A01 CSDL 01/1

A simple procedure was developed and applied for the grid generation around an airplane geometry. This approach is based

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on a transfinite interpolation with Lagrangian interpolation for the blending functions. A monotonic rational quadratic spline interpolation was employed for the grid distributions. Author

**N90-16252#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Hauptabteilung Windkanale.

**USE OF THE FILM-OF-OIL TECHNIQUE FOR PROFILE MEASUREMENTS IN THE TRANSONIC WIND TUNNEL BRUNSWICK (TWB) [EINSATZ DER OELANSTRICHTECHNIK BEI PROFILMESSUNGEN IM TRANSSONISCHEN WINDKANAL BRAUNSCHWEIG (TWB)]**

W. PUFFERT-MEISSNER /In DGLR, Two-Dimensional Measuring Techniques p 189-199 1988 In GERMAN  
Avail: NTIS HC A12/MF A02

The film-of-oil technique is applied in the TWB to support and interpret pressure distribution measurements on profiles in difficult flow conditions as well as for the investigation of sidewall effects on the profile flow. The film consists of silicone oil and colored powder; the mixture depends on the conditions. A video camera records the evolution of the film during the tests. The picture clearly shows the type and strength of the sidewall effect with increasing Mach number and angle of attack. The use of the film-of-oil technique as an interpretation aid for measured pressure distributions is demonstrated on a helicopter rotor blade. Infrared pictures show that the technique has its limitations in the determination of the laminar turbulent boundary layer transition since the film affects the boundary layer condition. ESA

## 03

### AIR TRANSPORTATION AND SAFETY

Includes passenger and cargo air transport operations; and aircraft accidents.

**A90-20390**

**THE AIRSHIP - AN ECONOMICAL ANSWER TO AIR CARGO**

ROY P. GIBBENS Huntsville Association of Technical Societies, Annual Technical and Business Exhibition and Symposium, 5th, Huntsville, AL, May 16, 17, 1989. 7 p.  
(TABES PAPER 89-1203) Copyright

At present, large and small aircraft provide for less than 2 percent of total freight moved in the world. This paper considers the potential role of airships as economical freight haulers. It is emphasized that, although the airship flies at only 100 mph, as compared to the aerodyne's 600 mph, airship is still much faster than any surface mode of transportation and have many advantages over the aerodyne. Airships are large and carry loads internally and externally, can operate from almost any large open area including lakes, and can hover to load and unload cargo. Airships could increase air cargo volume by 50 percent, a potential billion dollar industry. I.S.

**A90-20588#**

**AIRSHIP SURVIVAL - DAMAGE AVOIDANCE AND CONTROL FOR LARGE OCEAN-GOING AIRSHIPS**

G. S. SOMMER (Veda, Inc., Arlington, VA) and R. E. ADAMS (U.S. Navy, Naval Air Development Center, Warminster, PA) AIAA, Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989. 7 p. refs  
(AIAA PAPER 89-3166) Copyright

This paper outlines the philosophical basis for airship damage avoidance and control, with comparisons to heavier-than-air (HTA) and surface ship sensitivities. Historical instances where the application of damage avoidance and control principles either would have or did save the airship are examined. Drawing on the lessons of the past and on modern technology, some innovative concepts for damage minimization are presented. The conclusion of the

paper asserts that the large ocean-going airship of the future can be a failure-tolerant system if damage minimization is reflected in its design and operation. Author

**A90-20589#**

**AN ANALYTICAL TECHNIQUE FOR ADDRESSING AIRSHIP DITCHING BEHAVIOR**

DOMINIQUE FLEISCHMANN (Airship Industries /UK/, Ltd., London, England) AIAA, Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989. 24 p. refs  
(AIAA PAPER 89-3167) Copyright

Consideration is given to the methods used in a study to determine the hydrodynamic loads and pressures on the U.S. Navy Operational Development Model Airship during ditching onto water. Assumptions concerning the ditching conditions and the available analytical methods for studying the problem are reviewed. Summaries are given of a typical airship ditching geometry and the methods chosen to predict peak ditching pressures, pressure distribution over the bottom skin of the gondola, and the trajectory of the airship as it penetrates the water. Conclusions and recommendations concerning further studies of ditching behavior and airship design are presented. R.B.

**A90-22258#**

**DEVELOPMENT OF AN ANTI-ICING RUNBACK MODEL**

THEO G. KEITH, JR., KENNETH J. DE WITT (Toledo, University, OH), and KAMEL M. AL-KHALIL AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 12 p. Research sponsored by General Electric Co. refs  
(AIAA PAPER 90-0759) Copyright

In this paper a model for anti-icing runback water is developed. A continuous water layer in the direct impingement region is assumed to form individual, equally spaced, rivulets at breakup. The location of breakup is established based upon the local water film thickness and the operating conditions. The resulting wetness factor and rivulet geometrical properties are also determined. A closed form expression for the velocity distribution within a rivulet is obtained. Heat transfer calculation procedures and examples are introduced. Author

**A90-22735**

**TECHNICAL MEANS AND METHODS OF FLIGHT SAFETY ASSURANCE [TEKHNICHESKIE SREDSTVA I METODY OBESPECHENIIA BEZOPASNOSTI POLETOV]**

VLADIMIR G. VOROB'EV, BORIS V. ZUBKIOV, and BORIS D. URINOVSKII Moscow, Izdatel'stvo Transport, 1989, 152 p. In Russian. refs  
Copyright

Theoretical principles underlying flight safety assurance (FSA) are examined. A classification of technical means of FSA is given, and the impact of these tools on the FSA level is evaluated. Particular consideration is given to methods for assuring the flight safety of an aging fleet of aircraft. Aspects of FSA prediction and optimization are considered. B.J.

**N90-15048#** Technische Univ., Brunswick (Germany, F.R.). Inst. for Flight Guidance and Control.

**INFLUENCE OF WINDSHEAR, DOWNDRAFT AND TURBULENCE ON FLIGHT SAFETY**

GUNTHER SCHAEZNER /In AGARD, Flight in Adverse Environmental Conditions 19 p Sep. 1989  
Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Wind shear, downdraft, and turbulence influences flight safety especially in take-off and landing approach. For a better understanding of the relevant problems, the typical aircraft response in gust and in wind shear will be pointed out and will be compared with real flight situations. In general the airspeed deviation of an aircraft in a wind shear situation is relatively small in contrast to flight path deviations and flight performance is not the limiting factor. Flight simulator studies have shown that it is difficult for the cockpit crew to identify a wind shear situation without any



additional display of relevant information in order to control throttle and elevator in a correct manner. A wind shear warning display, based on energy deviation and energy rate can assist the pilot to overcome severe wind shear. Author

**N90-15062\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**NASA'S PROGRAM ON ICING RESEARCH AND TECHNOLOGY**  
JOHN J. REINMANN, ROBERT J. SHAW, and RICHARD J. RANAUDO / In AGARD, Flight in Adverse Environmental Conditions 31 p Sep. 1989 Previously announced as N89-22569  
Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01C

NASA's program in aircraft icing research and technology is reviewed. The program relies heavily on computer codes and modern applied physics technology in seeking icing solutions on a finer scale than those offered in earlier programs. Three major goals of this program are to offer new approaches to ice protection, to improve the ability to model the response of an aircraft to an icing encounter, and to provide improved techniques and facilities for ground and flight testing. The following program elements are reviewed: (1) new approaches to ice protection; (2) numerical codes for deicer analysis; (3) measurement and prediction of ice accretion and its effect on aircraft and aircraft components; (4) special wind tunnel test techniques for rotorcraft icing; (5) improvements of icing wind tunnels and research aircraft; (6) ground de-icing fluids used in winter operation; (7) fundamental studies in icing; and (8) droplet sizing instruments for icing clouds. Author

**N90-15065\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**EFFECTS OF LIGHTNING ON OPERATIONS OF AEROSPACE VEHICLES**

BRUCE D. FISHER / In AGARD, Flight in Adverse Environmental Conditions 14 p Sep. 1989  
Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive CSCL 01C

Traditionally, aircraft lightning strikes were a major aviation safety issue. However, the increasing use of composite materials and the use of digital avionics for flight critical systems will require that more specific lightning protection measures be incorporated in the design of such aircraft in order to maintain the excellent lightning safety record presently enjoyed by transport aircraft. In addition, several recent lightning mishaps, most notably the loss of the Atlas/Centaur-67 vehicle at Cape Canaveral Air Force Station, Florida in March 1987, have shown the susceptibility of aircraft and launch vehicles to the phenomenon of vehicle-triggered lightning. The recent findings of the NASA Storm Hazards Program were reviewed as they pertain to the atmospheric conditions conducive to aircraft lightning strikes. These data are then compared to recent summaries of lightning strikes to operational aircraft fleets. Finally, the new launch commit criteria for triggered lightning being used by NASA and the U.S. Defense Department are summarized. The NASA Research data show that the greatest probability of a direct strike in a thunderstorm occurs at ambient temperatures of about -40 C. Relative precipitation and turbulence levels were characterized as negligible to light for these conditions. However, operational fleet data have shown that most aircraft lightning strikes in routine operations occur at temperatures near the freezing level in non-cumulonimbus clouds. The non-thunderstorm environment was not the subject of dedicated airborne lightning research. Author

**N90-15067#** Office National d'Etudes et de Recherches Aérospatiales, Paris (France).

**PRINCIPAL CHARACTERISTICS OF LIGHTNING ON AIRCRAFT [PRINCIPALES CARACTERISTIQUES DES FOUDDROIEMENTS SUR AVIONS]**

J. L. BOULAY / In AGARD, Flight in Adverse Environmental Conditions 10 p Sep. 1989 In FRENCH Previously announced in IAA as A89-48744

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The modeling and measurement of lightning on aircraft are considered. Experimental studies were conducted which are based on the launching of small rockets with conducting wires attached to the ground. The study of the lightning-aircraft interaction involves the characterization of the direct effect of lightning on the aircraft, the affect of the electromagnetic field of nearby lightning, the distribution of the electrical and magnetic field components on the aircraft exterior and interior, and the effect of perturbations on on-board equipment. Results are presented for lightning strikes observed on the Transall and CV 580 aircraft. IAA

**N90-15083#** Army Aviation Engineering Flight Activity, Edwards AFB, CA.

**EVALUATION OF THE IMPROVED OV-ID ANTI-ICING SYSTEM, PHASE 2 Final Report, 6-23 Mar. 1989**

JOSEPH C. MIESS and GARY MCVANEY Apr. 1989 61 p  
Sponsored by Army Aviation Systems Command, Saint Louis, MO (AD-A213928; USAAEFA-87-25-1-PHASE-2) Avail: NTIS HC A04/MF A01 CSCL 08/12

The U.S. Army Aviation Engineering Flight Activity re-evaluated the OV-1 modified improved anti-icing system from 6 to 23 March 1989, at Duluth, Minnesota. Six flights (6.4 hours of cloud immersion) in natural icing conditions were conducted. Moderate icing conditions with temperatures less than -12 C were not encountered. One enhancing characteristic, seven deficiencies and five shortcomings were noted. The windshield anti-ice system enhances safe mission accomplishment. The seven deficiencies are as follows: the failure of the pneumatic deicing system to remove wing and empennage leading edge ice accumulations in moderate icing colder than -10 C; the failure of the anti-icing system to keep the engine inlet clear at temperatures colder than -10 C; the ice accretion and shedding characteristics of the propeller spinner afterbody which may result in ice foreign object damage (FOD) to the engine; the numerous converter dropouts during normal operation; the ice accretion characteristics of the pitot tube which result in erroneous airspeed indications; intermittent failure of the ice detector system to activate the anti-icing system; and the actions required to re-establish flight-essential and normal inverter loads following inverter dropout. GRA

**N90-15084#** Questek, Inc., Centerport, NY.

**SEE AND AVOID/COCKPIT VISIBILITY**

WALTON GRAHAM Oct. 1989 24 p Sponsored by FAA, Atlantic City, NJ  
(AD-A214214; DOT/FAA/CT-89/18) Avail: NTIS HC A02/MF A01 CSCL 01/2

This study was conducted in response to the Federal Aviation Administration's (FAA) Office of Aviation Safety and the recommendations of the Interagency Near Midair Collision (NMAC) Working Group, dated July 21, 1986, which suggested a review of see and avoid effectiveness, conspicuity enhancement, and their relationship to cockpit visibility. This report summarizes the salient facts in these areas, based on a review of the literature, and assesses the potential for significant reduction of collision risk. The study was conducted by Walton Graham, Questek, Incorporated, who was previously involved in numerous FAA see and avoid, pilot warning instrument/collision risk studies and analyses of the near midair collision data. GRA

**N90-15085#** Flight Safety Foundation, Inc., Arlington, VA.

**INTERNATIONAL AIRCRAFT OCCUPANT SAFETY CONFERENCE AND WORKSHOP PROCEEDINGS Final Report**  
Nov. 1988 309 p Conference held in Arlington, VA, 31 Oct. - 3 Nov. 1988  
(Contract DTFA01-88-C-0020)  
(AD-A214452; DOT/FAA/OV-89/2) Avail: NTIS HC A14/MF A02 CSCL 01/5

These proceedings contain formal conference presentations as well as summaries of informal workshop discussions on how to further improve aircraft cabin occupant safety. Also included are

## 03 AIR TRANSPORTATION AND SAFETY

the analysis and future recommendations for occupant safety. Session topics include: Inflight occupant protection; Passenger education; Crashworthiness; and Fire protection. GRA

**N90-15895#** National Transportation Safety Board, Washington, DC.

**AIRCRAFT ACCIDENT REPORT: DELTA AIR LINES, INC., BOEING 727-232, N473DA, DALLAS-FORT WORTH INTERNATIONAL AIRPORT, TEXAS, AUGUST 31, 1988**

26 Sep. 1989 137 p  
(PB89-910406; NTSB/AAR-89/04) Avail: NTIS HC A07/MF A01 CSCL 01/3

The crash of Delta flight 1141 while taking off at the Dallas-Fort Worth, Texas on August 31, 1988 is examined. The safety issues discussed include flightcrew procedures; wake vortices; engine performance; airplane flaps and slats; takeoff warning system; cockpit discipline; airplane rescue and firefighting; emergency evacuation; and survival factors. Recommendations addressing these issues were made to the Federal Aviation Administration, the American Association of Airport Executives, the Airport Operations Council International, and the National Fire Protection Association. Author

**N90-15896#** Royal Signals and Radar Establishment, Malvern (England).

**THE AUTOMATIC DETECTION OF ANTI-COLLISION LIGHTS**

BRIAN A. WYNDHAM Feb. 1989 19 p Sponsored by Civil Aviation Authority, London, England  
(RSRE-MEMO-4272; BR110168; ETN-90-96116) Copyright  
Avail: NTIS HC A03/MF A01

The techniques for the automatic detection of anti-collision lights, are presented. It is a warning system to be applied in light aircraft and helicopters. Instances of mid-air collisions and near-misses between aircraft at low level emphasize the need for some form of aid to provide earlier visual warning of potentially dangerous situations. The nature of the problem to be overcome, and proposals for the use of a cockpit image sensor and advanced image processing techniques, are described. ESA

**N90-15897** Civil Aviation Authority, London (England).

**UK AIRMISSES INVOLVING COMMERCIAL AIR TRANSPORT, SEPTEMBER TO DECEMBER 1988**

1989 50 p  
(ISSN-0951-6301; ETN-90-96148) Copyright Avail: Civil Aviation Authority, Greville House, 37 Graddon Road, Cheltenham, England, 5 sterling pounds

Airmisses in the United Kingdom involving commercial air transport aircraft, from Sep. - Dec. 1988, are reported. An airmis is said to occur when a pilot considers that his aircraft may be endangered by the proximity of another aircraft. The following topics are emphasized: the purpose and the investigation of the airmis reports, the categorization of the airmisses, the involvement of commercial air transport aircraft, and the relation of airmisses to flying hours. ESA

**N90-15898\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**PILOTED SIMULATION OF A GROUND-BASED TIME-CONTROL CONCEPT FOR AIR TRAFFIC CONTROL**

THOMAS J. DAVIS and STEVEN M. GREEN Jun. 1989 11 p  
Presented at the AIAA American Control Conference, Pittsburgh, PA, Jun. 1989  
(NASA-TM-101085; A-89085; NAS 1.15:101085) Avail: NTIS HC A03/MF A01 CSCL 01/3

A concept for aiding air traffic controllers in efficiently spacing traffic and meeting scheduled arrival times at a metering fix was developed and tested in a real time simulation. The automation aid, referred to as the ground based 4-D descent advisor (DA), is based on accurate models of aircraft performance and weather conditions. The DA generates suggested clearances, including both top-of-descent-point and speed-profile data, for one or more aircraft in order to achieve specific time or distance separation objectives. The DA algorithm is used by the air traffic controller to resolve

conflicts and issue advisories to arrival aircraft. A joint simulation was conducted using a piloted simulator and an advanced concept air traffic control simulation to study the acceptability and accuracy of the DA automation aid from both the pilot's and the air traffic controller's perspectives. The results of the piloted simulation are examined. In the piloted simulation, airline crews executed controller issued descent advisories along standard curved path arrival routes, and were able to achieve an arrival time precision of + or - 20 sec at the metering fix. An analysis of errors generated in turns resulted in further enhancements of the algorithm to improve the predictive accuracy. Evaluations by pilots indicate general support for the concept and provide specific recommendations for improvement. Author

## 04

## AIRCRAFT COMMUNICATIONS AND NAVIGATION

Includes digital and voice communication with aircraft; air navigation systems (satellite and ground based); and air traffic control.

**A90-20504**

**INTERFERENCE DETECTION AND SUPPRESSION IN LORAN-C RECEIVERS**

M. BECKMANN (Delft, Technische Universiteit, Netherlands) IEE Proceedings, Part F: Radar and Signal Processing (ISSN 0956-375X), vol. 136, pt. F, no. 6, Dec. 1989, p. 255-261. Research supported by the Stichting voor de Technische Wetenschappen. refs  
Copyright

With the expansion of the Loran-C radionavigation system in Europe, serious research into interference rejection techniques for Loran-C receivers is necessary. This is because the LF-spectrum is heavily used in Europe, and many signals in this frequency band can adversely affect Loran-C receiver performance. Previous analysis of interference signals has shown that the most important parameter determining the influence of an interference signal on receiver performance is its frequency. Conventional Loran-C receivers employ hardware filters to get rid of interference signals; a method for obtaining an optimum filter configuration in a specific area is described in the paper. New receiver designs can incorporate software rejection techniques and some kind of spectrum analysis to determine the frequencies of interference signals and therefore their influence on receiver performance. Such receivers can adapt themselves to changes in the interference spectrum. In the paper, a receiver architecture is presented which is optimally suited for spectral analysis. It makes heavy use of signal processing techniques. Author

**A90-20937**

**NEW APPROACH FOR DOPPLER AMBIGUITIES RESOLUTION IN MEDIUM PULSE REPETITION FREQUENCY RADARS**

G. ALBANO, S. CACOPARDI, and G. FEDELE (Roma I, Universita, Rome, Italy) Electronics Letters (ISSN 0013-5194), vol. 25, Nov. 23, 1989, p. 1672-1674. refs  
Copyright

A two-step procedure is proposed to extract target speed data in MPRF radars by starting from ambiguous measurements. This approach assures satisfactory performance for frequency-agile radars. Performance is assessed through a computer simulation for both fixed radio-frequency and radio-frequency hopping. C.D.

**A90-21378**

**AIR TRAFFIC CONTROL DEVELOPMENT AT LINCOLN LABORATORY**

PAUL R. DROUILHET, JR. (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 331-344. Research sponsored by FAA.  
Copyright

Advances in air traffic control aimed at improving surveillance,

communications, collision avoidance, and severe-weather sensing are examined. Consideration is given to the discrete address beacon system, Mode S, MLS, GPS, the Next-generation weather radar, moving target detection, the traffic advisory and collision avoidance system, and the parallel and converging runway monitor. Research in the area of data-link services are discussed. Current studies involve the development of techniques and algorithms to improve air traffic management. I.F.

## A90-21379

### THE MODE S BEACON RADAR SYSTEM

V. A. ORLANDO (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 345-362. Research sponsored by FAA. refs  
Copyright

The design and capabilities of the mode select beacon system (Mode S) are examined. Mode S provides better surveillance than the air traffic control radar beacon system (ATCRBS) and ground-air-ground data link for automation of air traffic control. The operation and design of the ATCRBS are described and its limitations are discussed. Particular attention is given to monopulse direction-finding techniques, Mode-S surveillance, and Mode-S integral data link. The applicability of the Mode-S design is evaluated experimentally. The implementation of Mode-S in the U.S. is discussed. I.F.

## A90-21380

### ADVANCES IN PRIMARY-RADAR TECHNOLOGY

M. L. STONE (MIT, Lexington, MA) and J. R. ANDERSON (Wisconsin, University, Madison) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 363-380. Research sponsored by FAA. refs  
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The design and operation of the moving target detector (MTD) are described. The MTD uses adaptive digital signal and data processing techniques. Functions of the MTD processor are: signal processing, thresholding, post-detection processing, area thresholding, and scan-to-scan correlation. The MTD is utilized in the Airport Surveillance Radar-9 (ASR-9); the ASR-9 provides near-optimal target-detection performance and weather data. Performance data revealing the applicability of the MTD are presented. I.F.

## A90-21381

### PROPAGATION OF MODE S BEACON SIGNALS ON THE AIRPORT SURFACE

M. L. WOOD (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 397-410. Research sponsored by FAA.  
Copyright

A design for propagation of Mode-S beacon signals on the airport surface is proposed. The system requires omnidirectional antennas equipped with an interrogation and/or receiver and the antennas are connected by cables to a control processing facility. Propagation difficulties caused by path loss attenuation, obstructions, and building reflections are examined. The applicability of Mode S for runway and taxiway surveillance is evaluated in terms of reflection and communications measurements. The data reveal that buildings affect the performance of Mode S as geometrically expected and that the reliability of Mode-S communications is good. I.F.

## A90-21382

### PARALLEL RUNWAY MONITOR

R. R. LAFREY (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 411-436. refs  
Copyright

The use of Mode-S secondary surveillance radars for monitoring parallel runway approaches is investigated. The limitations of dependent approaches and benefits of independent approaches are discussed. Data displaying the applicability of Mode S for surveillance, data display, automation, system performance, and user acceptance are presented and analyzed. It is noted that the

Mode-S sensor operates in the 2.4 sec back-to-back antenna mode and provides high-quality surveillance data during parallel-approach operations; the monitoring of arriving traffic and detection of deviations is improved; and a data base characterizing delay factors is derived. Diagrams of various runway approaches are provided. I.F.

## A90-21384

### MULTIPATH MODELING FOR SIMULATING THE PERFORMANCE OF THE MICROWAVE LANDING SYSTEM

J. E. EVANS, J. CAPON, and D. A. SHNIDMAN (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 459-474. refs  
Copyright

The development of a multipath model design to simulate MLS performance and multipath effects on the MLS is discussed. The basic characteristics of the MLS are described. Particular attention is given to specular ground, building, and aircraft reflections, shadowing by obstacles near the line of sight, and humped-runway shadowing. The capability of the simulation model is evaluated by comparing its output with measured antenna patterns and the data from bench tests on actual receivers. An example of the model's applicability is provided. I.F.

## A90-21387

### WIND SHEAR DETECTION WITH AIRPORT SURVEILLANCE RADARS

M. E. WEBER and T. A. NOYES (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 511-526. refs  
Copyright

The radar modifications and processing techniques needed to enable airport surveillance radars (ASRs) to detect wind shear are described. The role of the ASR-based wind shear detection system is discussed. Consideration is given to interference recognition, low-altitude velocity estimation, and automatic recognition of hazardous velocity divergence. The performance of the added signal channel and the processing techniques for the modified ASR are evaluated. The data reveal that the modified ASR can detect microbursts accompanied by rain at the surface with high confidence. I.F.

## A90-21388

### EXPERIMENTAL EXAMINATION OF THE BENEFITS OF IMPROVED TERMINAL AIR TRAFFIC CONTROL PLANNING

D. A. SPENCER, J. W. ANDREWS, and J. D. WELCH (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 527-536. Research supported by FAA. refs  
Copyright

Airport capacity can be improved significantly - by precisely controlling the sequence and timing of traffic flow - even when airspace usage and procedures remain fixed. In a preliminary experiment, a plan for such sequencing and timing was applied in a simulation to a 70-min traffic sample observed at Boston's Logan Airport, and the result was a 13 percent increase in terminal throughput. A total of 2.2 aircraft flight hours were saved. Delays imposed upon arriving traffic in the simulation were much more equitably distributed than in the actual traffic sample. An even greater improvement may be possible if controllers are able to space aircraft more precisely on final approach than was achieved in the simulation. If the plan had been followed precisely, the throughput increase would have been 23 percent. Author

## A90-21390

### USING AIRCRAFT RADAR TRACKS TO ESTIMATE WIND ALOFT

W. M. HOLLISTER, E. R. BRADFORD, and J. D. WELCH (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 555-565.  
Copyright

A method for estimating wind fields using aircraft radar tracks is described. The two main sources of error in radar-track measurements are acceleration and radar errors; however, these

errors do not affect the winds aloft estimates because they are reduced through statistical filtering. The effects of different range and bearing accuracy on wind estimates are examined. The algorithm is evaluated experimentally and it is observed that it provides useful wind field estimates. I.F.

## A90-21719#

### A GPS-BASED FLIGHT-CONTROL CONCEPT [FLUGFUEHRUNGSKONZEPT MIT GPS]

M. DIEROFF (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) *Ortung und Navigation* (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 379-387. In German. refs

Techniques for incorporating GPS position data into automatic flight-control systems are described. The fundamental principles of ILS control of approaches and landings in bad weather are reviewed; specific problems encountered in the intercept phase of an ILS approach are discussed; the real-time calculation of the required intercept path by a GPS-based navigation system is explained; and typical results from flight tests of a prototype system are presented in graphs and briefly characterized. In an automatic landing with a Do-28 test aircraft, the maximum divergence from the prescribed flight path was about 2 m. T.K.

## A90-21720#

### PRECISION NAVIGATION USING AN INTEGRATED GPS-IMU SYSTEM [PRAEZISIONSNAVIGATION MITTELS SYSTEMINTEGRATION VON GPS UND IMU]

TH. JACOB (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) *Ortung und Navigation* (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 402-414. In German. refs

The design principles and performance of air-navigation systems which combine satellite GPSs and onboard inertial measurement units (IMUs) are discussed. Consideration is given to the position-accuracy requirements for normal flight maneuvers and specific missions (geodesy, photogrammetry, laser profiling, and flight-path measurement), the error performance of differential GPS, and the short-term accuracy advantages of IMUs. Open-loop, closed-loop, and fully integrated GPS-IMU systems are shown in block diagrams and characterized in detail, and results from simulations and flight tests are presented graphically. A prototype system integrated by means of Kalman filtering demonstrated accuracy sufficient for ICAO CAT II landings, or even CAT III with respect to the horizontal precision. T.K.

## A90-21721#

### FLIGHT-PATH MEASUREMENT [FLUGBAHNVERMESSUNG]

MANFRED HAVERLAND (Aerodata Flugmesstechnik GmbH, Brunswick, Federal Republic of Germany) *Ortung und Navigation* (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 415-424. In German. refs

The accuracy requirements for commercial airport position-measurement systems are discussed, and the potential applicability of satellite GPSs in calibration testing of such systems is considered in detail. The fundamental principles of ILS flight control are reviewed; the ICAO-required periodic test procedures and typical test equipment are described; and the limitations imposed by current inertial navigation systems are pointed out. The differential GPS position-finding method is explained, and it is suggested that differential GPS is accurate enough to replace most optical measurement techniques, making the test procedure weather-independent and reducing the number of overflights required. T.K.

## A90-21722#

### DIFFERENTIAL GPS (DGPS) AS AN APPROACH AND LANDING AID [DIFFERENTIELLES GPS /DGPS/ ALS ANFLUG- UND LANDEHILFE]

HEINRICH REHMERT (Prakla-Seismos AG, Hanover, Federal Republic of Germany) *Ortung und Navigation* (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 425-433. In German.

DGPS techniques for achieving the position accuracy required for aircraft approach and landing (A&L) maneuvers are described. The key A&L problems are outlined; the definitions and accuracy

requirements of the ICAO ILS categories are summarized; and the relative merits of a DGPS-based A&L system are compared with those of MLS (currently scheduled for full implementation in the year 2000). Particular attention is given to the possible use of GPS or DGPS as a component of a DME/P system, the status of international standardization of DGPS, and system integrity issues. Preliminary flight-test results indicate that DGPS using the commercially available C/A code can meet the CAT I (and probably CAT II) horizontal and ranging accuracy requirements, but that additional data (e.g., from onboard altimeters) are necessary for adequate vertical precision. T.K.

## A90-21725#

### GROUND NAVIGATION IN AIRPORT TRAFFIC [BODENNAVIGATION IM FLUGPLATZVERKEHR]

*Ortung und Navigation* (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 455-476. In German. refs

The current status of traffic-control technology for aircraft moving on the ground at airports is surveyed, summarizing the interim results of a study being conducted by the DGON working group on ground navigation. Topics discussed include the applicable ICAO regulations, the possible use of satellite GPSs, the principal ground-traffic areas of an airport, and the general requirements for an integrated ground-navigation system. Particular attention is given to proposed systems based on (1) primary radars, (2) homing techniques, (3) video or IR cameras, (4) detectors and sensors mounted on the runways, (5) satellite navigation, and (6) secondary radars (mode S with data link). It is concluded that a combination of (1) and (6) offers the most practical alternative in the short term; the other options, while offering some specific improvements, at present fail to satisfy all of the general requirements. T.K.

## A90-22733

### RADIO DEVIATION OF AIRBORNE GONIOMETERS [RADIODEVIATSIIA SAMOLETNYKH BORTOVYKH UGLOMERNYKH USTROISTV]

EDUARD O. BRUDNYI, ALEKSANDR N. KORABLEV, and VIKTOR S. FEDCHENKO Moscow, Izdatel'stvo Transport, 1989, 240 p. In Russian. refs  
Copyright

General aspects of the theory and practice of the radio deviation of automatic radio compasses and aircraft radars are examined. Particular consideration is then given to the compensation of radio deviation in airborne radio compasses, practical recommendations on the choice of a site for radio-deviation operations in a typical airport, and error compensation for VLF goniometer systems. B.J.

## A90-23242#

### AN OPERATIONAL PERSPECTIVE OF POTENTIAL BENEFITS OF MICROWAVE LANDING SYSTEMS

JOHN N. BARRER and AGAM N. SINHA (Mitre Corp., McLean, VA) (National Convention of Aerospace Engineers, 3rd, New Delhi, India, Feb. 26, 27, 1988) *Institution of Engineers (India), Journal, Aerospace Engineering Division* (ISSN 0257-3423), vol. 69, Sept. 1988-Mar. 1989, p. 16-21. refs  
(Contract DTFA01-84-C-00001)

The operational requirements of the ground systems, avionics, and air traffic control procedures that are needed to derive the maximum operational benefits from an MLS are summarized. MLS applications are described, including reductions in route length, arrival and departure noise exposure, airspace conflicts. Also, consideration is given to improving airport capacity, operational restrictions due to ILS siting problems, and rotorcraft applications. R.B.

N90-15061# Royal Aircraft Establishment, Bedford (England). Flight Management Dept.

### THE ASSESSMENT OF VISIBILITY FROM AUTOMATIC CONTRAST MEASUREMENTS

A. W. PUFFETT In AGARD, *Flight in Adverse Environmental Conditions* 14 p Sep. 1989

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Visibility and hence runway visual range through the passive and automatic measurement of contrast reduction in a dark target are assessed. Though limited to use from dawn through to dusk the method offers significant advantages over the more usual transmission, or scattering approaches. The advantages arise not only from the measurement process which is intrinsically more robust than that of the transmissometer, but also from the radiometric manner in which it can be implemented. The result is a self-compensating system which virtually abolishes any requirement for temperature and long term stability in the instrument. Unlike conventional scatter-meters the method may be used under a wide range of obscuring conditions without doubts in respect of its constancy of sensitivity. Initial comparisons with a human observer have both produced good agreement and confirmed theoretical expectations of behavior. To overcome the night-time deficiency, suggestions are made for ways in which conventional measurements might be integrated into the system. The relaxation in design that would result from night-time only operation show this to be both a practical and economic alternative. Author

**N90-15086#** Mitre Corp., McLean, VA.  
**NATIONAL AIRSPACE SYSTEM: AIRPORT MOVEMENT AREA CONTROL OPERATIONAL CONCEPT Final Report**  
 A. LUCILLE SPRINGEN Sep. 1989 37 p  
 (Contract DTFA01-89-C-00001)  
 (WP-89W00181; DOT/FAA/DS-89/33; NAS-SR-13211) Avail: NTIS HC A03/MF A01

This concept of operations is one of a set that in total will describe the operation on the National Airspace System (NAS) when the projected upgrades are completed. As described in the National Airspace System Requirements Specification (NASSRS), Airport Movement Area Control involves the control and separation of aircraft and vehicles on the movement areas of qualifying aerodromes in all weather conditions, and includes the separation of aircraft from obstructions. Described here are specialists' functions necessary for the control of the airport movement area, most importantly, determining the identity and location of vehicles and aircraft on the movement area. This operational concept also describes interactions and information passed between the user, specialists, and NAS subsystems involved with airport movement area control in order to provide a common perspective for those engaged in this control. Author

**N90-15089#** Federal Aviation Administration, Atlantic City, NJ.  
**IMPROVED LIGHTING OF TAXIWAY/TAXIWAY INTERSECTIONS FOR INSTRUMENT FLIGHT RULES (IFR) OPERATIONS**

ERIC S. KATZ Dec. 1989 13 p  
 (DOT/FAA/CT-TN89/64) Avail: NTIS HC A03/MF A01

A new visual aid to advise pilots that a taxiway/taxiway intersection is being approached was developed at the Federal Aviation Administration (FAA) Technical Center. Subject pilots were asked to comment on the effectiveness of the new elevated taxiway intersection lights. Results of the evaluation indicate that the lights provide adequate advance warning of the approaching taxiway/taxiway intersection and an indication of where to stop to ensure clearance from aircraft using the intersecting taxiway. Author

**N90-15090#** Mitre Corp., McLean, VA.  
**CONTROL OUTSIDE OF INDEPENDENT SURVEILLANCE COVERAGE OPERATIONAL CONCEPT Final Report**

JILL B. RANDLETT Jun. 1989 37 p  
 (Contract DTFA01-89-C-0001)  
 (AD-A214163; DOT/FAA/DS-89/26; NAS-SR-1324) Avail: NTIS HC A03/MF A01 CSDL 17/7

This operational concept describes how Air Traffic Control (ATC) will be performed in non-radar (oceanic and mountainous terrain) areas throughout the National Airspace System (NAS). The

framework for this document incorporates non-radar ATC requirements from Section 3.2.4 of the NAS System Requirements Specification (NASSRS), the NAS Plan, and the NAS Level 1 Design, as expected to occur during the mid-to-late 1990's. The concept includes the functions provided by the Advanced Automation System (AAS) and Step 1 of the Automatic Dependent Surveillance (ADS) programs. GRA

**N90-15899#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

**ADVANCES IN TECHNIQUES AND TECHNOLOGIES FOR AIR VEHICLE NAVIGATION AND GUIDANCE**

WALTER M. HOLLISTER (Massachusetts Inst. of Tech., Cambridge.) 1990 13 p. Presented at the 48th Guidance and Control Panel Symposium, Lisbon, Portugal, 9-12 May 1989 (AGARD-AR-276; ISBN-92-835-0528-X) Copyright Avail: NTIS HC A03/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Papers were presented covering the following topics: terrain reference navigation methods; positioning by image processing or Global Positioning System (GPS); mission and sensor management; new techniques and algorithms; sensor technology; and systems applications. Author

**N90-15900#** Royal Signals and Radar Establishment, Malvern (England). Software Engineering Section.

**THE APPLICATION OF Z TO THE SPECIFICATION OF AIR TRAFFIC CONTROL SYSTEMS. 1: AN INITIAL SPECIFICATION OF THE RADAR PROCESSING ACTIVITY**

L. N. SIMCOX Apr. 1989 60 p Sponsored by Civil Aviation Authority, London, England  
 (RSRE-MEMO-4280; BR111060; ETN-90-96119) Copyright Avail: NTIS HC A04/MF A01

This initial investigation into the formal specification language Z and its applicability to air traffic control systems is described. The software corresponding to the initial radar plot processing in the multi-radar automatic tracking system at the London Air Traffic Control Centre (LATCC) is used. An informal pseudo code description of the radar plot processing function is taken as the requirements and converted into a formal specification in the Z language. The specification is partly validated, using a Royal Signals and Radar Establishment Z syntax and type checking tool. The experiences gained and potential benefits for the Civil Aviation Authority are discussed. ESA

## 05

### AIRCRAFT DESIGN, TESTING AND PERFORMANCE

Includes aircraft simulation technology.

**A90-20261**  
**CRASHWORTHINESS OF COMPOSITE FLOOR SECTIONS**

Aerospace Engineering (ISSN 0736-2536), vol. 9, Dec. 1989, p. 9-12.

Copyright

In order to evaluate the behavior of composite aircraft under various crash loading conditions, a joint U.S. Army/NASA research program has been conducted which encompassed static and dynamic testing of graphite-epoxy floor structures with and without surface skins. Each floor section had three graphite-epoxy semicircular flames, three aluminum floor beams, and 15 pultruded graphite-epoxy stringers. The nonlinear, dynamic structural finite-element code DYCAST was used to model the frames for both static and dynamic loading cases. The data generated by this test program will be used to develop more effective test techniques for impact-resistance potential in prospective structures. O.C.

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

**A90-20262**

### **EXTENDING AN AIRLINER'S LIFE**

Aerospace Engineering (ISSN 0736-2536), vol. 9, Dec. 1989, p. 13-15.

Copyright

The pressurized fuselage structural integrity problem that has emerged in long service-life B-737 airliners has prompted studies which have revealed that fatigue cracks tend to form readily in places where there are moderate stresses, or a knife-edged stress concentration, as well as repeated pressurization/depressurization cycles. As cracks propagate toward each other, the stress in the material increases, leading to an exponential growth of the crack-propagation rate. Attention is given to a rework program instituted for the B-737 which solves the structural-integrity problem by means of circumferential butt splices and lap splices. O.C.

**A90-20579#**

### **AN AEW METALCLAD AIRSHIP**

DONALD E. WOODWARD (Airships International, Inc., Tustin, CA) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 12-20. refs

(AIAA PAPER 89-3158) Copyright

This paper demonstrates that an AEW metalclad airship can fulfill many of the goals and requirements of the Naval Airship Program specification. A three-dimensional vectorable propulsor termed the '4-pi thruster' is presented. The metalclad weights are compared with a conventional rigid airship. Heavy vertical take-off with the diesel-driven 4-pi thrusters can lift enough fuel for 120 hours at 40 knots at 10,000 ft. The metalclad deadweight is approximately 5 1/2 percent greater than the conventional rigid airship. Author

**A90-20581#**

### **PRELIMINARY FEASIBILITY STUDY FOR A NEW HYBRID AIRSHIP (HELISHIP)**

SHIGENORI ANDO (Nagoya University, Japan) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 30-34.

(AIAA PAPER 89-3161) Copyright

The 'Heliship' configuration affixes a twin-rotor helicopter between two airship hulls. The three-body structure is interconnected by means of two (fore and aft) lateral beams which have airfoil cross-sections for aerodynamic efficiency. This configuration is presently suggested to create a synergism between helicopter and airship capabilities in which the positive aspects of each vehicle cancel out the other's negative characteristics. The concept promises low installed power requirements, good maneuverability, low vibration-induced damage, and high VTOL productivity. Performance comparisons are made with the 'Helistat' concept. O.C.

**A90-20582#**

### **A NEW HYBRID LTA VEHICLE, 'HELISHIP' - ITS PHILOSOPHY, OUTLINE**

KAZU IINUMA (Japan Buoyant Flight Association, Tokyo) and KO-ICHI SAITO IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 35-40. Research supported by the Hatachi Fund and Yamasaki Fund.

(AIAA PAPER 89-3162) Copyright

The 'Heliship' LTA vehicle configuration affixes a tandem-rotor helicopter between two ('catamaran') airship hulls by means of fore and aft, airfoil-section booms. A VTOL aircraft of this type is presented which can carry 100-150 passengers at speeds of the order of 100-150 km/hr, over a cruise radius of 300-600 km. The fare for passenger/km of a Heliship is expected to be comparable to that of taxi service in Japan. A comprehensive comparison is

made of performance capabilities between this aircraft and several representative conventional (rotary wing) VTOL and fixed-wing aircraft. O.C.

**A90-20583#**

### **A NEW TYPE OF NON-RIGID AIRSHIP SYSTEM**

M. ONDA (Mechanical Engineering Laboratory, Tsukuba, Japan) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 45-52.

(AIAA PAPER 89-3175) Copyright

The novel airship structural design presented is distinguished by a concentric axial duct, carrying the propulsion system for the craft and conducting its throughflow to an exhaust nozzle, extending from bow to stern. The improved steering performance characteristics sought through the thrust vectoring facilitated by this propulsion system geometry have been demonstrated with a scale model of the configuration. The flow of the propulsion system's intake and exhaust airflow is controlled by changing the orientation of the control surfaces located at the bow and stern openings of the axial duct. O.C.

**A90-20584#**

### **MODERN TECHNOLOGY IN AIRSHIP DESIGN**

A. W. L. NAYLER (Royal Aeronautical Society, London, England) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 53-59. refs

(AIAA PAPER 89-3169) Copyright

The state-of-the-art in materials, structures, CAD/CAM, fly-by-light controls, propulsion systems, and envelope and ballonet designs being used by airship manufacturers world-wide are evaluated. The most representative case of an airship integrating the whole range of advanced technologies is the U.S. Navy's YEZ-2A nonrigid, which is currently under construction and will begin test flights in 1992. The YEZ-2A will carry a large radar antenna within its envelope, to altitudes as high as 3 km, on long-endurance surveillance missions. O.C.

**A90-20585#**

### **CONTROL CONFIGURED AIRSHIP DESIGN**

B. L. NAGABHUSHAN (Saint Louis University, Cahokia, IL) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 60-66.

(AIAA PAPER 89-3170) Copyright

The control configured vehicle concept of relaxing inherent static stability is applied here to design a modern conventional or V/STOL airship which has fixed or vectorable cruise/lift propulsors and may have auxiliary thrust vector controls for pitch and directional control augmentation. It is shown that conventional control criteria can be met while significantly reducing the required empenage surface area, vehicle aerodynamic drag and weight by using this design approach. Albeit not a prerequisite for this application, the auxiliary thrust vector controls were found to allow greater reduction in fin size and to have favorable influence on the relaxed-stability vehicle performance at low speeds. These results are illustrated here by considering an example airship of 2.8 million cubic feet. Author

**A90-20586#**

### **PARAMETRIC SIZING OF MODERN NAVAL AIRSHIPS**

R. E. ADAMS (U.S. Navy, Naval Air Development Center, Warminster, PA) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 67-72.

(AIAA PAPER 89-3171)

A study was performed to examine the effects of mission requirements on naval airship size and performance. Sizing was



based on nonrigid airships due to the size and accuracy of the data base upon which the nonrigid sizing was based. An airship sizing and performance computer program was used to develop size trends for representative full-scale nonrigid naval airships. Limitations on nonrigid-airship maximum size were not addressed. Parameters examined included altitude, maximum speed, payload weight, cruise speed, and endurance. The results show the considerable impact of altitude requirements on airship size. Maximum speed requirements are of the same order of importance in vehicle sizing as altitude. The results show that vehicle size increases approximately linearly with both endurance and payload weight in the size range examined. The results indicate that nonrigid airships for the Navy's AAW mission lie within the 3-4 million cubic foot size range. Author

**A90-20587#****PREDICTION OF AEROSTAT AND AIRSHIP MOORING MAST LOADS BY NONLINEAR DYNAMIC SIMULATION**

S. P. JONES (Westinghouse Defense and Electronics Systems Co., Baltimore, MD) IN: AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers. Washington, DC, American Institute of Aeronautics and Astronautics, 1989, p. 73-77.  
(Contract N00019-87-C-0016)

(AIAA PAPER 89-3172) Copyright

The results of nonlinear dynamic simulations of a moored aerostat and two airships of different sizes, subjected to random turbulence, are presented and analyzed. The turbulence model was a frozen field, having a Dryden power spectrum, translated at the mean wind speed. When the rms components of nose load are normalized with respect to dynamic pressure and reference area, they are found to be smooth functions of rms gust angle computed from the mean wind and components of the turbulence. Based upon these results, curves are presented for the 99.87th percentile nose loads. An exception to the regular behavior was observed with the airships at 65 knots, where the higher frequency of the turbulence excited the 'bouncing' mode of the mass-landing gear system. Author

**A90-20590#****ESTIMATION OF THE FLIGHT DYNAMIC CHARACTERISTICS OF THE YEZ-2A**

K. R. NIPPRESS (Airship Industries /UK/, Ltd., London, England) and S. B. V. GOMES (Cranfield Institute of Technology, England) AIAA, Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, 9 p. refs

(AIAA PAPER 89-3173) Copyright

This paper presents an outline of the research conducted to enable estimation of the flight dynamic characteristics of the YEZ-2A Airship. The results obtained from correlation of theoretical techniques, wind tunnel work and available flight data will be presented and their impact on the development programme of the airship will be discussed. Author

**A90-21000****STOVL WIND TUNNEL TESTS DEMONSTRATE EJECTOR VIABILITY**

RICHARD G. O'LONE Aviation Week and Space Technology (ISSN 0005-2175), vol. 132, Jan. 8, 1990, p. 34, 35.

Copyright

The NASA-Ames low-speed wind-tunnel complex has recently hosted the testing of a full-scale model of the vertical thrust-augmenting ejector-incorporating E-7A STOVL fighter, using a 10,500-lb thrust Spey 801 engine. The ejector system's thrust-augmentation ratio of 1.58 is only slightly below the goal of 1.6 envisioned by its designers. The two previous research aircraft incorporating this thrust-augmenting principle for STOVL hovering flight were not able to exceed the augmentation value of 1.4. A test of the ejector system without the aircraft at NASA-Lewis yielded a ratio of 1.75. O.C.

**A90-21041#****PERFORMANCE AND AERODYNAMIC DEVELOPMENT OF THE SUPER PUMA MK II MAIN ROTOR WITH NEW SPP8 BLADE TIP DESIGN**

A. VUILLET, M. ALLONGUE (Aerospatiale, Division Helicopteres, Marignane, France), J. J. PHILIPPE, and A. DESOPPER (ONERA, Chatillon-sous-Bagneux, France) (European Rotorcraft Forum, 15th, Amsterdam, Netherlands, Sept. 12-15, 1989) ONERA, TP no. 1989-181, 1989, 20 p. refs  
(ONERA, TP NO. 1989-181)

The Super Puma Mk II helicopter is an up-graded version of the AS 332. It will have a more efficient enlarged main rotor in order to increase the max gross weight of the civil version from 8600 kg to 9070 kg. This paper covers the development work undertaken for the main rotor blades including a completely new blade tip shape with anhedral named SPP8. Its design is analyzed both on the theoretical and experimental viewpoints. The full capabilities of advanced three-dimensional aerodynamic design methods and of the experimental techniques in the wind tunnel and in flight has been used in collaboration with ONERA. Author

**A90-21048#****DETERMINATION OF THE GROUND EFFECT ON THE CHARACTERISTICS OF THE A320 AIRCRAFT [DETERMINATION DE L'EFFET DE SOL SUR LES CARACTERISTIQUES DE L'AVION A320]**

A. CONDAMINAS (Aerospatiale, Toulouse, France) and J. P. BECLE (ONERA, Modane, France) (NATO, AGARD, Fluid Dynamics Panel Symposium, Madrid, Spain, Oct. 2-5, 1989) ONERA, TP no. 1989-188, 1989, 13 p. In French.  
(ONERA, TP NO. 1989-188)

The ground effect on the aerodynamic response of the A320 is investigated experimentally using a 1:7.6-scale model equipped with two motorized nacelles in the S1 wind tunnel at ONERA Modane-Avrieux. The design and instrumentation of the model are described; the measurement apparatus and procedures are explained; and the results are presented in extensive graphs and characterized in detail. Particular attention is given to the treatment of the floor boundary layer and the corrections for the side walls and model support in the data analysis. Good general agreement with flight-test data is demonstrated with respect to lift and mean deflection; the airspeed errors are found to be comparable to the precision of the pressure sensors. T.K.

**A90-21156\*** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**HYPERSONIC AIRBREATHING VEHICLE DESIGN - FOCUS ON AERO-SPACE PLANE**

JAMES L. HUNT (NASA, Langley Research Center, Hampton, VA) IN: Hypersonics. Volume 1 - Defining the hypersonic environment; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 205-262. refs  
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Creating a viable, 'aerospaceplane' airbreathing SSTO vehicle will require sophisticated configuration synthesis and a synergistic integration of advanced technologies across the spectrum of disciplines. In design exercises conducted to date, reductions in the fuel weight-fraction requirement can result from improvements in aerodynamics/controls, enhanced propulsion efficiencies, and trajectory optimization. Additional improvements in fuel-weight fraction can result from improvements in structural design, heat-management techniques, and materials properties. O.C.

**A90-21171****HYPERSONIC FLIGHT TESTING**

WALTON E. WILLIAMSON, JR. (Sandia National Laboratories, Albuquerque, NM) IN: Hypersonics. Volume 2 - Computation and measurement of hypersonic flows; Proceedings of the First Joint Europe/U.S. Short Course on Hypersonics, Paris, France, Dec. 7-11, 1987. Boston, MA, Birkhaeuser, 1989, p. 431-459.  
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While ground testing and prediction techniques are needed for

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

the preliminary design of hypersonic flight vehicles, the data thus obtained have been noted to often miss some essential element of actual flight performance. The only way to adequately ascertain whether all requisite elements have been taken into consideration is by conducting flight tests which will verify predictions and furnish high vehicle-design confidence. Flight test options notably include small but highly instrumented unmanned models launched by rockets; highly developed procedures exist for the use of the measurements obtained to verify or falsify theoretical models.

O.C.

### A90-21275

#### **DURABILITY OF EQUIPMENT ASSEMBLIES AND ELEMENTS OF LIFE-SUPPORT SYSTEMS FOR FLIGHT VEHICLES [PROCHNOST' AGREGATOV OBORUDOVANIIA I ELEMENTOV SISTEM ZHIZNEOBESPECHENIIA LETATEL'NYKH APPARATOV]**

EVGENII P. BOLENSKII, BORIS I. SAKHAROV, and NIKOLAI P. STREKOZOV Moscow, Izdatel'stvo Mashinostroenie, 1989, 248 p. In Russian. refs

Copyright

Methods for calculating the durability of various construction elements involved in systems of flight vehicles are discussed with particular consideration given to calculations of durability for thick-walled and thin-walled structures of mechanical equipment and for life-support-system structures that are based on fabric materials. Attention is also given to the basic methods of dynamic calculations for the structures of life-support systems, calculations of the service life of a construction element from the characteristics of the fatigue-fracture resistance, and questions of mechanical reliability of life-support-system structures.

I.S.

### A90-21610#

#### **DESIGN CRITERIA, CONSTRUCTIONS, AND MATERIALS FOR THE DORNIER 328 AIRFRAME**

LOTHAR BRENNER and EBERHARD JOHST Dornier Post (ISSN 0012-5563), no. 3, 1989, p. 60-63.

Copyright

The materials-selection and structural design efforts associated with development of the 30-33 passenger Dornier 328 regional airliner, which is equipped with a fully pressurized cabin, are discussed. The service life requirement for the airframe without major repairs was taken to be 50,000 flight hours/65,000 flights; high resistance to birdstrike damage and very low cabin noise levels were additional criteria to be met within the lowest possible production costs. CADAM was employed throughout the design/manufacturing cycle.

O.C.

### A90-21611#

#### **LOW- AND HIGH-SPEED TESTS WITH THE DORNIER 328 WIND-TUNNEL MODEL**

HARTMUT BUERS, PETER ESCH, and GUENTHER HALFMANN Dornier Post (ISSN 0012-5563), no. 3, 1989, p. 64-66.

Copyright

While large, operationally expensive wind tunnels have had to be used to accommodate a 1:4.2-scale wind tunnel model of the Dornier 328 regional airliner, these methods have the singular advantage of allowing such small components as control surfaces and trim tabs to be more reliably studied for effects on overall flight-mechanical characteristics. Low-speed tests ascertained the optimum takeoff and landing configurations of the control surfaces; high-speed tests, to Mach 0.66, gave attention to the longitudinal stability effects of compressibility phenomena.

O.C.

### A90-21703

#### **STOWING THE TILT-ROTOR**

JAMES H. BRAHNEY Aerospace Engineering (ISSN 0736-2536), vol. 10, Jan. 1990, p. 19-22.

Copyright

A structural-mechanical system is under development which will allow the V-22 tilt-rotor VTOL aircraft to be operated from, and stowed aboard, small ships as well as aircraft carriers, by allowing the wing to be rotated to a position in which it lies along

the fuselage's longitudinal axis. This rotation reduces the 25.8 x 19.1 m dimensions of the V-22 with wings and rotors deployed to 5.6 x 19.1 m with the wings and rotor blades stowed. The wing rotation actuator uses a translating ballscrew and driving nut assembly as the actuation element.

O.C.

### A90-21710

#### **ADVANCED TECHNOLOGY ROTORCRAFT - CIVIL SHORT HAUL TRANSPORT OF THE FUTURE**

JOHN W. LEVERTON (E.H. Industries, Inc., Arlington, VA) Vertiflite (ISSN 0042-4455), vol. 36, Jan.-Feb. 1990, p. 26-32. refs

Copyright

The use of rotorcraft for short haul/commuter services is discussed. The advantages and disadvantages of using rotorcraft are studied in terms of operation costs, airport/airspace congestion, and time savings. Consideration is given to operational requirements, safety factors, design standards, and dispatch reliability. The development of heliports or vertiports, which would improve the payload/performance of rotorcraft. Diagrams of proposed heliports are provided.

I.F.

### A90-21711

#### **THE COMING AGE OF THE TILTROTOR. I**

PHILIP C. NORWINE (Bell Helicopter Textron, Inc., Fort Worth, TX) Vertiflite (ISSN 0042-4455), vol. 36, Jan.-Feb. 1990, p. 39-46.

Copyright

The design and applicability of the tiltrotor, V-22, are described. Tiltrotor aircraft combine helicopterlike vertical flight ability with turboprop speed, altitude, and range. The V-22 tiltrotor is designed as a multimission, multiservice aircraft; a list of some of its functions is provided. The V-22 has an operational weight of 25 tons, 24 seats, a rear ramp for loading cargo, an internal capacity of 9 tons, and can carry up to 6 tons of fuel. Particular attention is given to the aircraft gearbox. The application of the V-22 tiltrotor for commercial use is discussed.

I.F.

### A90-21712

#### **TW-68 TILT WING HIGH SPEED COMMERCIAL VTOL**

TAIICHI ISHIDA and IWAO NAKATANI Vertiflite (ISSN 0042-4455), vol. 36, Jan.-Feb. 1990, p. 47-49.

Copyright

The development of tiltrotor and tilt-wing aircraft is discussed. These aircraft can provide high speed capability with good hovering. The propulsion system and commercial seating capacity for tiltrotor or tilt-wing configurations are examined. The design and development of the TW-68 tilt-wing aircraft are described.

I.F.

### A90-21713

#### **EAST COAST OSPREY FLIES**

JULIAN MOXON Flight International (ISSN 0015-3710), vol. 137, Jan. 3, 1990, p. 22, 23.

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Some of the testing and evaluation of the V-22 Osprey are described. Problems with the gearbox, engine nacelle, and exhaust-gas recirculation and the correction of these difficulties are discussed. Attention is given to the Osprey performance while in aircraft mode and taking off and landing with the aircraft.

I.F.

### A90-22001#

#### **NEW PROGRESS IN AIRFRAME DURABILITY REQUIREMENTS**

ZHENG WANG (Chengdu Aircraft Co., People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, Dec. 1989, p. B570-B575. In Chinese, with abstract in English. refs

The development history of airframe durability requirements in China and abroad is reviewed in this paper. Emphasis is given to a survey of the basic ideas, characteristics, wide application fields, and a variety of objectives and integrity systems of durability design in the new durability requirements. Two kinds of durability analysis approaches and the distinguishing feature of durability tests are

briefly presented. The relation and difference among the designs of durability, safe-life, and damage tolerance are stated. Author

**A90-22434**

**COCKPIT EVOLUTION IN AIRBUS**

UDO GUENZEL (Airbus Industrie, Blagnac, France) IN: Systems analysis in aerospace; Proceedings of the Symposium, London, England, May 11, 12, 1988. London, Royal Aeronautical Society, 1988, p. 18-27.

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The cockpit instrument display design effort had, as its basic criteria, (1) that all system elements would have to be sufficiently redundant to survive failures, (2) that engine primary operating parameters would be displayed, (3) that no more than six CRTs would be employed, and (4) that two sidesticks would be provided to pilots on outboard consoles. An account is presently given of the logic by which the A320 airliner's cockpit design was developed within this framework. The 7.25 x 7.25-inch CRTs used are capable of accepting the four sets of engine instruments required, in a round-dial presentation. O.C.

**A90-22734**

**AIRCRAFT OF UNCONVENTIONAL CONFIGURATION (2ND REVISED AND ENLARGED EDITION) [SAMOLETY OSOBYKH SKHEM /2ND REVISED AND ENLARGED EDITION/]**

DMITRII A. SOBOLEV Moscow, Izdatel'stvo Mashinostroyeniya, 1989, 176 p. In Russian. refs

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The history of aircraft with unconventional aerodynamic configurations is surveyed. The design, development, and applications of the following types of configurations are examined: tailless, canard, tandem, and ring-wing. B.J.

**A90-23113#**

**DIGITAL CONTROL OF LOCAL SOUND FIELDS IN AN AIRCRAFT PASSENGER COMPARTMENT**

J. V. WARNER and R. J. BERNHARD (Purdue University, West Lafayette, IN) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 284-289. Previously cited in issue 04, p. 439, Accession no. A88-16558. refs

(Contract NSF MSM-85-05834)

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**A90-23117\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**OPTIMAL PLACEMENT OF TUNING MASSES FOR VIBRATION REDUCTION IN HELICOPTER ROTOR BLADES**

JOCELYN I. PRITCHARD and HOWARD M. ADELMAN (NASA, Langley Research Center, Hampton, VA) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 2, p. 837-849) AIAA Journal (ISSN 0001-1452), vol. 28, Feb. 1990, p. 309-315. Previously cited in issue 12, p. 1826, Accession no. A88-32260. refs

Copyright

**A90-23200**

**SIZING UP THE STEALTH**

JOE MIZRAHI Wings, vol. 20, Feb. 1990, p. 20-48.

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A comprehensive account is given of the design philosophy, operational requirements, performance capabilities and fabrication methodology of the USAF B-2 'Stealth' bomber. An evaluation is also made of the anticipation of various important features of the all-wing B-2 design by the experimental tailless bombers produced by Northrop in the 1950s. Attention is given to the careful balance employed between internal, primary loadbearing metallic structural components and external, radar-absorbing composite panels, as well as the wholesale employment of CAD/CAM facilities to minimize design development and production time. Political aspects of B-2 development funding and the prospects for procurement are discussed. O.C.

**A90-23276\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**HYPERSONIC AEROSPACE SIZING ANALYSIS FOR THE PRELIMINARY DESIGN OF AEROSPACE VEHICLES**

GARY J. HARLOFF and BRIAN M. BERKOWITZ (NASA, Lewis Research Center; Sverdrup Technology, Inc., Cleveland, OH) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 97, 98. Previously announced in STAR as N89-15107. refs

(Contract NAS3-24105)

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A review of the hypersonic literature indicated that a general weight and sizing analysis was not available for hypersonic orbital, transport, and fighter vehicles. The objective here is to develop such a method for the preliminary design of aerospace vehicles. This report describes the developed methodology and provides examples to illustrate the model, entitled the Hypersonic Aerospace Sizing Analysis (HASA). It can be used to predict the size and weight of hypersonic single-stage and two-stage-to-orbit vehicles and transports, and is also relevant for supersonic transports. HASA is a sizing analysis that determines vehicle length and volume, consistent with body, fuel, structural, and payload weights. The vehicle component weights are obtained from statistical equations for the body, wing, tail, thermal protection system, landing gear, thrust structure, engine, fuel tank, hydraulic system, avionics, electrical system, equipment payload, and propellant. Sample size and weight predictions are given for the Space Shuttle orbiter and other proposed vehicles, including four hypersonic transports, a Mach 6 fighter, a supersonic transport (SST), a single-stage-to-orbit (SSTO) vehicle, a two-stage Space Shuttle with a booster and an orbiter, and two methane-fueled vehicles. Author

**A90-23352**

**FATIGUE DAMAGE OF AN AIRCRAFT DUE TO MOVEMENT ON THE AIRFIELD [UNAVOVE POSKOZENI LETOUNU OD POHYBU PO ZEMI]**

JOSEF VLACHYNSKY Zpravodaj VZLU (ISSN 0044-5355), no. 4, 1989, p. 191-196. In Czech. refs

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Four methods for calculating the fatigue damage of an aircraft due to movement on the airfield are described: (1) a method based on the linear summation hypothesis, with fatigue damage calculated from the loading spectrum; (2) a method based on the linear summation hypothesis, with fatigue damage calculated from the increment load factor spectrum; (3) a method based on the hypothesis of the spectral summation of loading energy, with fatigue damage calculated from the loading spectrum; and (4) a method based on the spectral summation hypothesis, with fatigue damage calculated from the spectral density of airfield roughness. The application of these methods is illustrated by calculating the fatigue damage in the rear longeron of a landing gear moving on a concrete airfield at a speed of 30 km per hour. B.J.

**A90-23363**

**ANALYSIS OF THE MATHEMATICAL MODELING OF AN AIRCRAFT FLIGHT TRAJECTORY WITH CONSIDERATION OF ENGINE THRUST EFFECT ON THE FORCE RATIO ON THE AIRCRAFT [ROZBOR MATEMATICKEHO MODELOVANI TRAJEKTORIE LETOUNU S UVAZENIM VLIVU TAHU POHONNE JEDNOTKY NA SILOVE POMERY NA LETOUNU]**

MIROSLAV SIVAK Zpravodaj VZLU (ISSN 0044-5355), no. 5, 1989, p. 297-301. In Czech. refs

Copyright

The motion of an aircraft is described by equations of motion with different degrees of simplification. The model is refined by considering the angle of attack effect on the thrust vector and thus also on the magnitude of aerodynamic forces. The basic and refined model are analyzed. The models are compared from the point of view of deviations of necessary aerodynamic coefficient values for the horizontal flight of subsonic and supersonic aircraft. Author

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

**N90-15042#** Flight Safety Foundation, Inc., Arlington, VA.

### **THE HUMAN ELEMENT: THE KEY TO SAFE, CIVIL OPERATIONS IN ADVERSE WEATHER**

JOHN H. ENDERS *In* AGARD, Flight in Adverse Environmental Conditions 7 p Sep. 1989

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The problems of civil flight in adverse weather was discussed in general terms and specific examples were used to illustrate the nature of technical, procedural and human factors, with a view toward the mitigation of serious events. Author

**N90-15058\*#** Georgia Inst. of Tech., Atlanta. School of Aerospace Engineering.

### **A STUDY OF THE EFFECTS OF ROTATING FRAME TURBULENCE (RFT) ON HELICOPTER FLIGHT MECHANICS**

D. P. SCHRAGE, J. V. B. PRASAD, and G. H. GAONKAR (Florida Atlantic Univ., Boca Raton.) *In* AGARD, Flight in Adverse Environmental Conditions 13 p Sep. 1989

(Contract NCA2-266)

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The turbulence actually experienced by a helicopter blade-element significantly differs from the space-fixed free atmospheric turbulence. The turbulence in the rotor disk requires a rotationally sampled description in a rotating frame of reference. It is referred to as the rotating frame turbulence or RFT which exhibits a striking phenomenon. The RFT spectral density versus frequency shows high peak values at 1P, 2P, or 3P, frequencies. The energy increase at these peaks is balanced by an energy decrease primarily at the lower-than-1P frequency range. Particularly for low altitude flight regimes of pure helicopters, such as the nap-of-the-earth maneuvers, the conventional space-fixed description of turbulence is not a good approximation, since the turbulence scale length can have values comparable to the rotor radius. Accordingly the flight mechanics characteristics with RFT description are compared with those based on the conventional space-fixed turbulence description. The results demonstrate that the RFT qualitatively and quantitatively affects the prediction of helicopter flight mechanics characteristics in turbulence. Such comparisons should play an important role in the new development of handling qualities' specifications for helicopters. Author

**N90-15063#** Texas A&M Univ., College Station. Dept. of Aerospace Engineering.

### **ICE INDUCED AERODYNAMIC PERFORMANCE DEGRADATION OF ROTORCRAFT: AN OVERVIEW**

K. D. KORKAN and R. K. BRITTON *In* AGARD, Flight in Adverse Environmental Conditions 34 p Sep. 1989

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The renewed interest in evaluating the performance degradation of helicopters due to icing has resulted in the development of methodologies to analytically predict the aerodynamic degradation increment. The progress in understanding the basic icing technology is reviewed citing major references. The analytical methodology is then summarized with respect to performance degradation of propellers, helicopter in hover, helicopter in forward flight, and the forerunner of the V-22 Osprey, the XV-15 propulsion model(s). The experimental studies of the NACA 0012 airfoil with/without generic ice and the model helicopter main rotor experiments with/without generic ice are reviewed. Based upon these results, refinements are suggested to the current methodology with respect to near term/far term. Author

**N90-15066#** Aeroplane and Armament Experimental Establishment, Boscombe Down (England).

### **AIRCRAFT TESTING IN THE ELECTROMAGNETIC ENVIRONMENT**

P. M. NEWTON *In* AGARD, Flight in Adverse Environmental

Conditions 8 p Sep. 1989

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Testing aircraft flight safety critical systems against the effects of electromagnetic interference (EMI) is normally performed on the ground for reasons of safety, practicality and cost. The threat and the effects of EMI on aircraft systems is discussed. The current ground test methods used at Aeroplane and Armament Experimental Establishment (A and AEE) are reviewed, including the limitations, uncertainties of measurement and safety margins. A flight test method for assessing the effects on critical systems from both the on-board and external electromagnetic environment is described which should enable the ground test results to be factored thus providing a more precise clearance for service use without compromising safety. Author

**N90-15093\*#** ACA Industries, Inc., Rancho Palos Verdes, CA.

### **APPLICATION OF THE JOINED WING TO TILTROTOR AIRCRAFT**

JULIAN WOLKOVITCH, BARNABY WAINFAN, YITZHAK BEN-HARUSH, and WAYNE JOHNSON (Johnson Aeronautics, Palo Alto, CA.) Nov. 1989 94 p

(Contract NAS2-12988)

(NASA-CR-177543; NAS 1.26:177543) Avail: NTIS HC A05/MF A01 CSCL 01/3

A study was made to determine the potential speed improvements and other benefits resulting from the application of the joined wing concept to tiltrotor aircraft. Using the XV-15 as a baseline, the effect of replacing the cantilever wing by a joined-wing pair was studied. The baseline XV-15 cantilever wing has a thickness/chord ratio of 23 percent. It was found that this wing could be replaced by a joined-wing pair of the same span and total area employing airfoils of 12 percent thickness/chord ratio. The joined wing meets the same static strength requirements as the cantilever wing, but increases the limiting Mach Number of the aircraft from  $M=0.575$  to  $M=0.75$ , equivalent to an increase of over 100 knots in maximum speed. The joined wing configuration studied is lighter than the cantilever and has approximately 11 percent less wing drag in cruise. Its flutter speed of 245 knots EAS is not high enough to allow the potential Mach number improvement to be attained at low altitude. The flutter speed can be raised either by employing rotors which can be stopped and folded in flight at speeds below 245 knots EAS, or by modifying the airframe to reduce adverse coupling with the rotor dynamics. Several modifications of wing geometry and nacelle mass distribution were investigated, but none produced a flutter speed above 260 knots EAS. It was concluded that additional research is required to achieve a more complete understanding of the mechanism of rotor/wing coupling. Author

**N90-15094\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **SERRATED TRAILING EDGES FOR IMPROVING LIFT AND DRAG CHARACTERISTICS OF LIFTING SURFACES Patent Application**

PAUL M. H. W. VIJGEN, inventor (to NASA) (Kansas Univ., Lawrence.), FLOYD G. HOWARD, inventor (to NASA), DENNIS M. BUSHNELL, inventor (to NASA), and BRUCE J. HOLMES, inventor (to NASA) 30 Nov. 1989 16 p Sponsored by NASA (NASA-CASE-LAR-13870-1; US-PATENT-APPL-SN-429516; NAS 1.71:LAR-13870-1) Avail: NTIS HC A03/MF A01 CSCL 01/3

An improvement in the lift and drag characteristics of a lifting surface is achieved by attaching a serrated panel to the trailing edge of the lifting surface. The serrations may have a saw-tooth configuration, with a 60 degree included angle between adjacent serrations. The serrations may vary in shape and size over the span-wise length of the lifting surface, and may be positioned at fixed or adjustable deflections relative to the chord of the lifting surface. NASA

**N90-15095#** Virginia Univ., Charlottesville. School of Engineering and Applied Science.

**EFFECTS OF AEROELASTIC TAILORING ON ANISOTROPIC COMPOSITE MATERIAL BEAM MODELS OF HELICOPTER BLADES M.S. Thesis**

PATRICK GRAHAM FORRESTER May 1989 164 p  
(AD-A213478) Avail: NTIS HC A08/MF A01 CSCL 01/3

The role of composite materials in modern helicopter blade design has become most important during recent years. By exploiting the directional stiffness properties of these composites, favorable torsion modes or twisting can be achieved. The capability to apply this potential as a design parameter is generally known as aeroelastic tailoring. The bending-torsional coupling of static, hingeless composite rotor blades is investigated using finite element theory. The hingeless blade is treated as a single cell laminated shell beam. Each laminate is composed of different lay-ups of graphite-epoxy composite plies and is categorized as isotropic or anisotropic based upon this lay-up. A systematic study is made to identify the effects of ply orientation and lamina thickness on blade section properties. The results of this study are used to solve the beam equations for composite materials. GRA

**N90-15096#** Air Force Flight Test Center, Edwards AFB, CA.  
**SCHLEICHER ASK-21 GLIDER (TG-9) STALL AND SPIN Final Report**

DOYLE B. JANZEN and CHARLES J. PRECOURT Jul. 1989 129 p  
(AD-A213513; AFFTC-TR-89-27) Avail: NTIS HC A07/MF A01 CSCL 01/1

The results of the Schleicher ASK-21 Glider (TG-9) Stall and Spin Evaluation are documented. Testing included evaluation of the departure and spin susceptibility of the aircraft as a function of weight and cg, definition of spin modes and modes characteristics as well as the control effects on those modes. Stall and spin flight tests of the ASK-21 were conducted between at the Air Force Flight Test Center (AFFTC), Edwards AFB, California. GRA

**N90-15097#** Air Force Inst. of Tech., Wright-Patterson AFB, OH.

**AIRCRAFT PERFORMANCE ENHANCEMENT WITH ACTIVE COMPRESSOR STABILIZATION M.S. Thesis**

JOHN G. SEYMOUR 1988 224 p  
(AD-A213652; AFIT/CI/CIA-88-228) Avail: NTIS HC A10/MF A02 CSCL 01/1

An engine cycle deck and a mission simulation program were mated to provide the capability to analyze the impact of localized design changes in a systems context. Specifically, the effects of compressor stall alleviation accomplished through the use of active stabilization were analyzed. Since no experimental data exists for compressor performance in the actively stabilized region of operation, actual compressor performance was bracketed by the examination of two types of compressors; one having steeply sloped speed lines in the actively stabilized region and the other having speed lines with shallow slope. Engines with actively stabilized compressor sections were installed in an advanced tactical fighter and flown through a typical high-low-high attack profile. Mission performance results for the aircraft with controlled compressors were compared to baseline values of mission radius, takeoff gross weight, aircraft operating weight and aircraft total wetted area. Efficiency, engine radius at the fan and bare engine weight were found to be the primary determinants of mission performance. GRA

**N90-15098#** Army Aviation Research and Development Command, Moffett Field, CA. Aeroflightdynamics Directorate.

**AN EXAMINATION OF HELICOPTER ROTOR LOAD CALCULATIONS**

THOMAS H. MAIER 1988 20 p  
(AD-A214295) Avail: NTIS HC A03/MF A01 CSCL 20/11

The structural response of three full-scale helicopter rotors has been examined. Airloads predicted by CAMRAD were compared by harmonics with test measurements. Flapwise bending

moments were calculated from the CAMRAD airloads using three methods: force integration, curvature, and a finite-difference method. The force-integration and curvature moments were calculated with the CAMRAD program itself; however, the finite-difference method was calculated externally by a forced response program, Blade Response to Aerodynamic Loading (BRAL). The BRAL analysis with measured airloads was shown to agree well with strain-gauge measurements on the CH-34 rotor in a wind tunnel. The CAMRAD/force-integration bending moments were shown to accumulate error as the integration progressed from tip to root. The CAMRAD/curvature moments agreed well with the finite-difference moments over most of the blade; however, at regions of rapidly changing stiffness the agreement was poor. When applied to the BRAL solution, force integration was shown to give excellent results, provided the integration had a small step size. Shear forces calculated by CAMRAD and BRAL showed fair agreement. GRA

**N90-15099#** Aerolift, Inc., Tillamook, OR.

**X.2 LIMITED FLIGHT TEST PLAN**

15 Mar. 1989 85 p  
(Contract MDA972-88-C-0058)  
(AD-A214412) Avail: NTIS HC A05/MF A01 CSCL 01/3

The X.2 Limited Flight Test Plan is for the CycloCrane Program. The principal objectives of the planned tests are to: (1) assess a number of ground handling scenarios for the X.2 system to determine the preferred mix of Ground Support Equipment (GSE) and personnel for efficient and safe field operations, and (2) obtain specific performance data needed to support design development; e.g., hover power of new, four engine configuration. The aerostat has a diameter of 68 feet and is 136 feet long. The fabric is a polyurethane coated dacron. The X.2 CycloCrane is powered by four Hirth F-30 (110 horsepower each) two-stroke engines. The total weight of these four engines with reduction belt drives and exhaust manifolds is 440 pounds. The four propellers are wooden, three-bladed fixed pitch with a diameter of 92 inches. The telemetry subsystem has been upgraded to accommodate the installation of four engines place of the original two. It has a truly remote control operation and is relatively simple but reliable. GRA

**N90-15100\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**THE EFFECTIVENESS OF VANE-AILERON EXCITATION IN THE EXPERIMENTAL DETERMINATION OF FLUTTER SPEED BY PARAMETER IDENTIFICATION**

ELI NISSIM (Technion - Israel Inst. of Tech., Haifa.) Jan. 1990 23 p  
(NASA-TP-2971; H-1516; NAS 1.60:2971) Avail: NTIS HC A03/MF A01 CSCL 01/3

The effectiveness of aerodynamic excitation is evaluated analytically in conjunction with the experimental determination of flutter dynamic pressure by parameter identification. Existing control surfaces were used, with an additional vane located at the wingtip. The equations leading to the identification of the equations of motion were reformulated to accommodate excitation forces of aerodynamic origin. The aerodynamic coefficients of the excitation forces do not need to be known since they are determined by the identification procedure. The 12 degree-of-freedom numerical example treated in this work revealed the best wingtip vane locations, and demonstrated the effectiveness of the aileron-vane excitation system. Results from simulated data gathered at much lower dynamic pressures (approximately half the value of flutter dynamic pressure) predicted flutter dynamic pressures with 2-percent errors. Author

**N90-15902\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**EVALUATION OF TWO TRANSPORT AIRCRAFT AND SEVERAL GROUND TEST VEHICLE FRICTION MEASUREMENTS OBTAINED FOR VARIOUS RUNWAY SURFACE TYPES AND CONDITIONS. A SUMMARY OF TEST RESULTS FROM JOINT FAA/NASA RUNWAY FRICTION PROGRAM**

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

THOMAS J. YAGER, WILLIAM A. VOGLER (PRC Kentron, Inc., Hampton, VA.), and PAUL BALDASARE Washington Feb. 1990 301 p  
(NASA-TP-2917; L-16536; NAS 1.60:2917) Avail: NTIS HC A14/MF A02 CSCL 01/3

Tests with specially instrumented NASA Boeing 737 and 727 aircraft together with several different ground friction measuring devices were conducted for a variety of runway surface types and conditions. These tests are part of joint FAA/NASA Aircraft/Ground Vehicle Runway Friction Program aimed at obtaining a better understanding of aircraft ground handling performance under adverse weather conditions and defining relationships between aircraft and ground vehicle tire friction measurements. Aircraft braking performance on dry, wet, snow and ice-covered runway conditions is discussed as well as ground vehicle friction data obtained under similar runway conditions. For a given contaminated runway surface condition, the correlation between ground vehicles and aircraft friction data is identified. The influence of major test parameters on friction measurements such as speed, test tire characteristics, type and amount of surface contaminant, and ambient temperature are discussed. The effect of surface type on wet friction levels is also evaluated from comparative data collected on grooved and ungrooved concrete and asphalt surfaces.

Author

**N90-15904#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

### FUEL TANK TECHNOLOGY

Nov. 1989 171 p In ENGLISH and FRENCH Meeting held in Ottawa, Ontario, 23-28 Apr. 1989

(AGARD-R-771; ISBN-92-835-0534-4) Copyright Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Experiences and information concerning aircraft fuel tank technology, and information concerning current design practices were exchanged and detection and repair of fuel leaks and modification practices to improve fuel tank integrity were discussed.

**N90-15905#** British Aerospace Public Ltd. Co., Kingston-upon-Thames (England).

### INTEGRAL FUEL TANK SEALING PRACTICE AT BRITISH AEROSPACE (KINGSTON)

G. N. SHERIDAN In AGARD, Fuel Tank Technology 7 p Nov. 1989

Copyright Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The current integral fuel tank sealing and repair procedures at British Aerospace (Kingston) were reviewed. It describes the materials and processes used in the design and initial manufacture of integral fuel tanks. The methods used for the repair of leaks in integral fuel tanks are described. The need to review the current procedures for use on future aircraft using composite materials is highlighted.

Author

**N90-15906#** Avions Marcel Dassault, Saint-Cloud (France).

### INTEGRAL FUEL TANKS - DESIGN, PRODUCTION, AGING, REPAIR [LES RESERVOIRS DE CARBURANT STRUCTURAUX CONCEPTION, REALISATION, VIEILLISSEMENT, REPARATION]

C. A. PICARD In AGARD, Fuel Tank Technology 12 p Nov. 1989 In FRENCH

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The advantages of using integral tanks for aircraft fuel containment are discussed and compared to those of flexible fuel tanks. The design elements of integral tanks that ensure leak-proof characteristics are described including joints, fasteners, and ports. Various types of leakage problems are outlined and repair methods

are discussed. Finally, the problem of microbial corrosion is addressed.

Transl. by M.G.

**N90-15907#** Aeritalia S.p.A., Turin (Italy). Defence Aircraft Group.

### AIRCRAFT FUEL TANK CONSTRUCTION AND TESTING EXPERIENCE

ERNESTO LIOSSI and CORRADO BIANCO In AGARD, Fuel Tank Technology 18 p Nov. 1989

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The evolution of aircraft structures manufacturing technology has moved the choice of solutions for fuel tanks, from welded sheet metal components to flexible rubber fuel cells up to now when airplanes manufacturers are going to address their choices, toward more extensive adoption of integral fuel tanks. The Aeritalia experience in fuel tanks construction is presented with a short view on flexible fuel tank applications (advantages and disadvantages) and the technological solutions adopted for integral fuel tanks construction and performances quality assurance. The integral fuel tanks are designed as primary structures to sustain high loads, therefore the critical target is to obtain a leak proof structure and to guarantee no leakage for the aircraft service-life.

Author

**N90-15908#** Royal Air Force, Dereham (England).

### THE REPAIR OF AIRCRAFT INTEGRAL FUEL TANKS IN THE RAF: A USER'S VIEW OF FUEL TANK TECHNOLOGY

G. DAWSON In AGARD, Fuel Tank Technology 8 p Nov. 1989

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The sealing and repair of aircraft fuel tanks was a thorn in the side of aircraft maintenance personnel for a considerable number of years. In the Royal Air Force in particular, repairing and resealing integral fuel tanks was always difficult and has frequently required several attempts to achieve an acceptable seal. In justifying this repair expenditure, it would be easy to conclude that all problems resulted from poor design, ineffective sealants, poor information or even bad weather. However, although all of these factors play a part in repair procedures, some problems were generated for ourselves, and these require considerable commitment on the part of the managers to resolve. Some progress was already made in resolving the more critical of the problems, and the success rate in effective, long-term repairs has begun to improve. However, it is expected that the process of gradual improvement will continue for the foreseeable future. In order to achieve this improvement, a number of areas of concern were summarized, beginning with background to fuel tank repair in the RAF, and including Health and Safety problems, leak testing, tank venting, surface preparation and resealing. In each area both equipment and procedures are being continually improved in order to reduce aircraft downtime and improve repair effectiveness at all depths of maintenance. Finally, the problems generated by aircraft design, and in particular access provided to integral fuel tanks are examined. As in the other areas, we have identified problems and suggested improvements for future aircraft as well as highlighting the reliability and maintainability implications of poor design. The problems faced by Royal Air Force maintenance engineers in repairing aircraft integral fuel tanks are documented.

Author

**N90-15913#** Messerschmitt-Boelkow-Blohm G.m.b.H., Munich (Germany, F.R.). Military Aircraft Div.

### DESIGN PHILOSOPHY AND CONSTRUCTION TECHNIQUES FOR INTEGRAL FUSELAGE FUEL TANKS

G. KAGERBAUER, M. VOGLSINGER, and L. LEMMER In AGARD, Fuel Tank Technology 20 p Nov. 1989

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The fuel tanks of modern military aircraft are designed as integral fuel tanks. The design features and sealing systems which were adopted for integral fuselage fuel tanks, to satisfy the requirement for tightness during the entire service life, are presented. The design aim was to minimize penetrations into the fuel compartments and to reduce the probability of fuel leaks by the application of redundant sealing barriers. The adopted sealing systems for the sealing of internal metallic substructure, and to an outer CFRP skin are described. Selected sealing systems were tested in a representative sideskin test box in fatigue and the experience gained was introduced into the design of a fuselage sealing box to aircraft standard which was also tested in fatigue. The representative fuel tank structure of the sealing box was used to demonstrate accessibility for repair and to prove that repair actions to the sealing system are possible with suitable equipment. Author

**N90-15914#** Lockheed Aeronautical Systems Co., Marietta, GA. **FUEL TANK EXPLOSION PROTECTION** M. E. BORDERS, G. E. KNOWLES, D. E. MEADOWS, C. C. RANDALL, T. F. CHRISTIAN, JR., and T. M. JENNINGS (Warner Robins Air Logistics Center, Robins AFB, GA.) In AGARD, Fuel Tank Technology 17 p Nov. 1989 Copyright Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The modernization of military aircraft has included the addition of fuel tank fire/explosion protection. A military transport, like any other aircraft, is susceptible to fuel tank explosions from a number of sources, including combat gunfire. Studies have shown that the fuel tanks are the largest single contributor to the vulnerability from high explosive incendiary (HEI) rounds for transport aircraft. Since no aircraft has the inherent capability to suppress flames within the fuel tank ullage, it is important to provide a tank explosion protection system that prevents fires and explosions inside the fuel tanks during all modes of aircraft operation. The Lockheed Aeronautical Systems Company and the United States Air Force have acquired considerable knowledge about explosive suppressant foam through its use in the Lockheed-built C-130 aircraft. This foam material prevents or limits flame and pressure wave propagation and acts as an anti-slosh baffle. In-service experience with the foam is discussed. Associated maintenance problems and impacts on man-hours, weight, and cost is also reviewed. The status of the new foam materials being developed to eliminate electrostatic problems with the present explosion suppressant foam will be stated and assessed. Alternative techniques and methods to achieve fuel tank explosion protection were proposed for the C-130 and will be compared to the performance of the foam installation. Finally, explosion suppression is put into perspective with other C-130 wing modernization features. Author

**N90-15915#** McDonnell Aircraft Co., Saint Louis, MO. Structural Dynamics Dept.

**A DYNAMICIST'S VIEW OF FUEL TANK SKIN DURABILITY** M. A. FERMAN, M. D. HEALEY, W. H. UNGER, and MARTIN D. RICHARDSON (Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.) In AGARD, Fuel Tank Technology 17 p Nov. 1989

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Widespread leakage of fuel tanks in military aircraft is believed to be aggravated by small cracks induced by premature fatigue of skins from fluid structure interaction loading and dynamics. A developing method is shown that will help improve designs to avoid this recently recognized problem. The technique treats flat panels, curved panels, and stiffened panels. Parallel panels configured as sides or top and bottom pairs are included. Panels of a representative fuel tank section of typical aircraft construction were analyzed, tested, and are included. This method was under steady and careful development for a number of years so that

high confidence would be established at each step. A well balanced analytical and experimental approach was taken. It is now mature and ready for full scale application. Author

**N90-15916#** Air Force Wright Research and Development Center, Wright-Patterson AFB, OH.

#### **INTEGRAL FUEL TANK CERTIFICATION AND TEST METHODS**

MARTIN D. RICHARDSON In AGARD, Fuel Tank Technology 13 p Nov. 1989

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Fuel tanks make up a significant structural volume of present aircraft designs. Life cycle costs and the repair of fuel tank leaks are significant. The efforts accomplished, and now in progress, to develop methods to certify the fuel containment integrity of future USAF aircraft are described. The methods use the idea of combining the aircraft structural durability testing requirements with a fuel tank certification requirement. The application of this concept during the development phase of a new aircraft design will enable deficiencies in fuel tank sealing designs to be discovered early, before production begins. The work accomplished to date using C-130 wing fuel tank components, has shown that this approach is possible and does provide valid results. The requirement to employ environmental exposures, including the use of actual jet fuels, and not water or simulants, is emphasized. Author

**N90-15917#** Royal Aerospace Establishment, Farnborough (England).

#### **THE DEVELOPMENT OF A LOW COST DATA LOGGING SYSTEM FOR FLIGHT TRIALS BASED ON AN IBM COMPATIBLE PC**

A. P. MANNING Jan. 1989 24 p (RAE-TM-FM-16; BR110742; ETN-90-96130) Copyright Avail: NTIS HC A03/MF A01

The development of a data logging system based on an IBM compatible Personal Computer (PC), is described. It is extended to both the airborne and ground based data recording capabilities. The new system supplements the existing Modular Data Acquisition System (MODAS) fitted to the research aircraft. The compatibility with existing recovery and plotting systems, is maintained. It provides a portable record/replay capability and allows operations remote from base with immediate access to data, currently between sorties and potentially between runs in a sortie. ESA

**N90-15930#** Lockheed Missiles and Space Co., Austin, TX.

#### **UNMANNED AIR VEHICLES PAYLOADS AND SENSORS**

GROVER S. AMICK In AGARD, Guidance and Control of Unmanned Air Vehicles 18 p Aug. 1989

Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The Lockheed Corporation developed a family of payload sensors for use in unmanned air vehicle applications. The program was initially conceived as an extension of the U.S. Army Aquila Remotely Piloted Vehicle (RPV) Program and is applicable to a much wider variety of uses and applications. The design concept utilized a universal gimbal platform with interchangeable sensor spheres. The concept and implementation process was directed to develop a low-cost sensor system which could easily accommodate new sensors as they become available. The system has been developed and demonstrated using the Lockheed Altair UAV system and is available for use. A family of seven sensor types were successfully demonstrated, and others are in development. The system is known as the Lockheed Adaptive Modular Payload System (LAMPS). Author

**N90-15933#** Lockheed Missiles and Space Co., Austin, TX.

#### **DISTRIBUTION OF HARDWARE AND SOFTWARE ELEMENTS IN UNMANNED AIR VEHICLE SYSTEMS**

LARRY D. SAUVAIN In AGARD, Guidance and Control of Unmanned Air Vehicles 10 p Aug. 1989

## 05 AIRCRAFT DESIGN, TESTING AND PERFORMANCE

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Future unmanned air vehicle systems will be highly automated in order to accomplish their intended mission. These increased levels of automation are best achieved when the computer and man-machine interface elements are incorporated into the initial system design. Adequate capacity, growth capabilities and the maximum use of previously developed system elements are essential considerations in the computer hardware selection. The software structure must be modular, maintainable and have adequate configuration management tools to assure that the correct software is in use at all times. Since additional unplanned mission requirements may evolve, it is important that the man-machine interface elements be easily reconfigured. The basis for these assertions and how they were achieved within the ground control station portion of the Lockheed Demonstration and Research Test System will be addressed. Author

**N90-15934#** British Aerospace Public Ltd. Co., Lancashire (England). Military Aircraft Div.

### TECHNOLOGY AND EVALUATION OF UNMANNED AIR VEHICLES

GEORGE R. SEYFANG /in AGARD, Guidance and Control of Unmanned Air Vehicles 5 p Aug. 1989

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The 15 years of UMA studies and experimental work done at BAe indicate that all of the technologies required to allow UMA to fulfill the air-to-ground roles in increasingly dangerous scenarios now exist. There appears to be the potential for significant savings in peacetime operating costs with UMA, although there would have to be changes to the services' infrastructure to gain all of these potential savings. Author

## 06

### AIRCRAFT INSTRUMENTATION

Includes cockpit and cabin display devices; and flight instruments.

#### A90-21383

##### TCAS - A SYSTEM FOR PREVENTING MIDAIR COLLISIONS

W. H. HARMAN (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 437-458. refs Copyright

The development and operation of the Traffic Alert and Collision Avoidance System (TCAS) are described. TCAS is an airborne electronics system that uses radio signals for surveillance of the transponders of nearby aircraft and cockpit displays and auditory alarms to warn pilots of a potential collision. The interrogation/reply technique of TCAS is employed to detect the presence and measure the location of all aircraft within 15 miles; the traffic-advisory-display aide indicates a range of 2 nmiles. The advantages of TCAS for avoidance detection of the air-to-air surveillance and the various TCAS classes are discussed. The performance of the air-to-air surveillance and alarm triggering subsystems of the TCAS are examined. An example of the TCAS display is provided. I.F.

#### A90-21609#

##### DIGITAL MAP FOR HELICOPTER NAVIGATION AND GUIDANCE

WERNER BAUSCH and INGO LIEBIG Dornier Post (ISSN 0012-5563), no. 3, 1989, p. 46, 47. Copyright

Digital maps such as those generated by the presently discussed 'DKG' electronic map system, by contrast with conventional map-display units, are noted to furnish superior

navigational support on helicopter cockpit screens, as well as an entirely novel mode of situational awareness. Onboard DKG equipment encompasses an image/map-storage unit and a digital map multiprocessor system; these are interconnected via high-speed digital interface. In order to facilitate map legibility, details can be continuously magnified or reduced ('zoomed').

O.C.

#### A90-22614#

##### INFRARED SOURCES OF JET PROPULSION SYSTEM AND THEIR SUPPRESSION

QINGFAN ZHANG (Nanjing Aeronautical Institute, People's Republic of China) Journal of Propulsion Technology (ISSN 1001-4055), Dec. 1989, p. 29-32, 71. In Chinese, with abstract in English. refs

Infrared sources of jet propulsion systems were analyzed and their suppression techniques were discussed in this paper. Infrared radiation of the systems are caused by high temperature due to fuel combustion, and can be grouped into two kinds: radiation from solid surface and radiation from exhaust gases. Generally, the suppression techniques for the infrared radiation include three aspects: (1) lowering radiation surface temperature by cooling and/or insulating, or blocking propagation of infrared rays; (2) speeding mixing processes between exhaust gas and surrounding air; (3) diluting radiative species of combustion products. Author

#### A90-23245#

##### TRENDS IN AVIONICS - FROM ANALOG BLACK BOXES TO INTEGRATED DIGITAL AVIONICS SYSTEMS

M. BOEHM (Standard Elektrik Lorenz AG, Stuttgart, Federal Republic of Germany) (National Convention of Aerospace Engineers, 3rd, New Delhi, India, Feb. 26, 27, 1988) Institution of Engineers (India), Journal, Aerospace Engineering Division (ISSN 0257-3423), vol. 69, Sept. 1988-Mar. 1989, p. 29-41. refs

An overview of West German aerospace avionics research is presented, covering airborne avionics topics such as tactical air navigation, the joint tactical information distribution system, and GPS. Consideration is given to the introduction of digital technologies, computers as avionics elements, and redundant integrated avionics. The trends for future satellite-based communications, navigation, and identification and surveillance avionics are examined. R.B.

**A90-23284\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

##### AIRBORNE DOPPLER RADAR DETECTION OF LOW-ALTITUDE WIND SHEAR

E. M. BRACALENTE, W. R. JONES (NASA, Langley Research Center, Hampton, VA), and C. L. BRITT (Research Triangle Institute, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 151-157. Previously cited in issue 22, p. 3652, Accession no. A88-51911. refs Copyright

**N90-15102\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

##### DISPLAY INTERFACE CONCEPTS FOR AUTOMATED FAULT DIAGNOSIS

MICHAEL T. PALMER Dec. 1989 34 p (NASA-TM-101610; NAS 1.15:101610) Avail: NTIS HC A03/MF A01 CSCL 01/4

An effort which investigated concepts for displaying dynamic system status and fault history (propagation) information to the flight crew is described. This investigation was performed by developing several candidate display formats and then conducting comprehension tests to determine those characteristics that made one format preferable to another for presenting this type of information. Twelve subjects participated. Flash tests, or limited time exposure tests, were used to determine the subjects' comprehension of the information presented in the display formats. It was concluded from the results of the comprehension tests that pictographs were more comprehensible than both block diagrams and text for presenting dynamic system status and fault

history information, and that pictographs were preferred over both block diagrams and text. It was also concluded that the addition of this type of information in the cockpit would help the crew remain aware of the status of their aircraft. Author

## 07

## AIRCRAFT PROPULSION AND POWER

Includes prime propulsion systems and systems components, e.g., gas turbine engines and compressors; and on-board auxiliary power plants for aircraft.

A90-20431

**EFFECT OF THE NONUNIFORM ROTATION OF THE GAS TURBINE ROTOR ON BLADE VIBRATIONS [O VLIANII NERAVNOMERNOSTI VRASHCHENIIA ROTORA GAZOTURBINNOGO DVIGATELIA NA KOLEBANIIA RABOCHIKH LOPATOK]**

V. N. VERNIGOR and I. A. ZELENKOV. IN: Stability and vibrations of mechanical systems. Leningrad, Izdatel'stvo Leningradskogo Universiteta, 1988, p. 82-86. In Russian. refs

Copyright

The paper is concerned with the vibrations of the blades of aviation gas turbines resulting from nonuniform changes in the angular velocity of the rotor. The problem of determining the blade deflection is reduced to that of solving the problem of the vibrations of a rotating elastic rod with concentrated masses. Results of deflection calculations are presented and compared with blade deflections under conditions of aerodynamic flow nonuniformity.

V.L.

A90-21031#

**THERMODYNAMICS AND THE FUTURE TURBINE ENGINES**

M. BARRERE (ONERA, Chatillon-sous-Bagneux, France) ONERA, TP no. 1989-165, 1989, 16 p. refs (ONERA, TP NO. 1989-165)

Prospective designs for the propulsion systems for civilian transport aircraft are examined, focusing on the thermodynamic aspects of engine design. The technological challenges of high-speed and orbital flight are discussed. Several propulsion systems are described, including variable cycle systems and hybrid systems. Consideration is given to various combustors, ejectors and augmenters, and several types of fuels used in airbreathing propulsion systems.

R.B.

A90-21224#

**CALCULATED CHEMICAL AND VIBRATIONAL NONEQUILIBRIUM EFFECTS IN HYPERSONIC NOZZLES**

OUSSAMA RIZKALLA, WALLACE CHINITZ, and JOHN I. ERDOS (General Applied Science Laboratories, Inc., Ronkonkoma, NY) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 50-57. Research supported by USAF. Previously cited in issue 19, p. 3181, Accession no. A88-46503. refs

Copyright

A90-21225\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**PARAMETRIC STUDIES OF ADVANCED TURBOPROPS**

D. G. FERTIS (Akron, University, OH), R. A. AIELLO, C. C. CHAMIS (NASA, Lewis Research Center, Cleveland, OH), and J. G. MASER (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers. Part 1, p. 431-440) Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 58-62. Previously cited in issue 12, p. 1831, Accession no. A88-32223. refs

Copyright

A90-21228#

**NONAXISYMMETRIC INSTABILITIES IN A DUMP COMBUSTOR WITH A SWIRLING INLET FLOW**

M. SAMIMY, C. A. LANGENFELD (Ohio State University, Columbus), A. S. NEJAD (USAF, Aero Propulsion Laboratory, Wright-Patterson AFB, OH), and S. C. FAVALORO Journal of Propulsion and Power (ISSN 0748-4658), vol. 6, Jan.-Feb. 1990, p. 78-84. Research supported by USAF. Previously cited in issue 07, p. 951, Accession no. A88-22137. refs

Copyright

A90-21607#

**DIGITAL ELECTRONIC CONTROL UNIT FOR THE EUROPEAN FIGHTER AIRCRAFT (EFA)**

UWE SCHULZ and RAINER KAERCHER Dornier Post (ISSN 0012-5563), no. 3, 1989, p. 30-32.

Copyright

The EFA's EJ200 engine digital engine control unit (DECU) controls fuel flow, afterburner fuel-metering valves, variable area-nozzle position, and compressor air flow. The DECU also monitors the performance of the associated control system sensors and actuators. DECU architecture and packaging are compact and flexible; the two-lane, full-authority DEC lies in a single housing, with both lanes being physically separated. The DECU achieves significant improvements over existing systems in weight, reliability, and performance, while minimizing acquisition costs.

O.C.

A90-21627#

**SOME ASPECTS OF THE EROSION WEAR OF COMPONENTS OF AIRCRAFT TURBINE ENGINES [NIEKTORE ZAGADNIENIA EROZYJNEGO ZUZYCIA ELEMENTOW LOTNICZYCH SILNIKOW TURBINOWYCH]**

EMIL WEGRZYN (Instytut Mechaniki Precyzyjnej, Warsaw, Poland) Technika Lotnicza i Astronautyczna (ISSN 0040-1145), vol. 44, July 1989, p. 8-10. In Polish. refs

The effect of contaminated air on the components of turbine engines is considered. Methods for investigating friction erosion and for correlating it with material properties are examined. Methods for preventing erosive wear are also discussed.

B.J.

A90-21949\* Princeton Univ., NJ.

**HYPERSONIC PROPULSION**

SIN-I. CHENG (Princeton University, NJ) Progress in Energy and Combustion Science (ISSN 0360-1285), vol. 15, no. 3, 1989, p. 183-202. refs

(Contract NAS1-17234)

Copyright

The paper reviews the whys and hows of the concept of supersonic combustion for hypersonic propulsion. Attention is given to the problem areas, the current research and development efforts, and their implications. The operating boundary of the SCRAMJET is reasonably well defined. The paper also explores some air-breathing alternatives that may go beyond SCRAMJETS.

Author

A90-22652#

**FUEL MOLECULAR STRUCTURE AND FLAME TEMPERATURE EFFECTS ON SOOT FORMATION IN GAS TURBINE COMBUSTORS**

O. L. GULDER, B. GLAVINCEVSKI, and M. F. BAKSH (National Research Council of Canada, Div. of Mechanical Engineering, Ottawa) ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN 0022-0825), vol. 112, Jan. 1990, p. 52-59. refs

(ASME PAPER 89-GT-288) Copyright

A systematic study of soot formation along the centerlines of axisymmetric laminar diffusion flames of a large number of liquid hydrocarbons, hydrocarbon blends, and aviation turbine and diesel fuels was made. Measurements of the attenuation of a laser beam across the flame diameter were used to obtain the soot volume fraction, assuming Rayleigh extinction. Two sets of hydrocarbon blends were designed such that the molecular fuel composition varied considerably but the temperature fields in the flames were

kept practically constant. Thus it was possible to separate the effects of molecular structure and the flame temperature on soot formation. It was quantitatively shown that the smoke point height is a lumped measure of fuel molecular constitution. The developed empirical relationship between soot volume fractions and fuel smoke point and hydrogen-to-carbon ratio was applied to five different combustor radiation data, and good agreement was obtained. Author

**A90-22664#**

### **EFFECT OF INLET FLOW ANGLE ON THE EROSION OF RADIAL TURBINE GUIDE VANES**

H. EROGLU and W. TABAKOFF (Cincinnati, University, OH) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 112, Jan. 1990, p. 64-70. Research supported by DOE. refs (ASME PAPER 89-GT-208) Copyright

The results of an investigation of the particle dynamics and the blade erosion at the impact locations in radial turbine guide vanes are presented. Attention is focused in particular on the effect of inlet flow angle on the erosion of the blades, since the flow entering the guide vanes usually has an incidence angle due to the upstream scroll geometry. The total erosion per blade is calculated as a function of inlet flow angle for three different particle diameters, which are 5, 15, and 60 microns, respectively. According to the results of this investigation, for each particle size there is an inlet flow angle for minimum erosion of the guide vanes. This fact has to be accounted for in the design of radial turbines operating in particulate flow environments. Author

**A90-22665#**

### **SIMULATION OF COMPRESSOR PERFORMANCE DETERIORATION DUE TO EROSION**

W. TABAKOFF, A. N. LAKSHMINARASIMHA (Cincinnati, University, OH), and M. PASIN ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 112, Jan. 1990, p. 78-83. refs (ASME PAPER 89-GT-182) Copyright

Experimental results obtained from cascades and single-stage compressor performance tests before and after erosion were used to test a fault model to represent erosion. This model was implemented on a stage stacking program developed to demonstrate the effect of erosion in a multistage compressor. The effect of individual stage erosion on the overall compressor performance is also demonstrated. Author

**A90-22667#**

### **A COMPARISON BETWEEN THE DESIGN POINT AND NEAR-STALL PERFORMANCE OF AN AXIAL COMPRESSOR**

N. M. MCDUGALL (Cambridge, University, England) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 112, Jan. 1990, p. 109-115. Research supported by Rolls Royce, PLC and SERC. refs (ASME PAPER 89-GT-70) Copyright

Detailed measurements have been made within an axial compressor operating both at design point and near stall. Rotor tip clearance was found to control the performance of the machine by influencing the flow within the rotor blade passages. This was not found to be the case in the stator blade row, where hub clearance was introduced beneath the blade tips. Although the passage flow was observed to be altered dramatically, no significant changes were apparent in the overall pressure rise or stall point. Small tip clearances in the rotor blade row resulted in the formation of corner separations at the hub, where the blade loading was highest. More representative clearances resulted in blockage at the tip due to the increased tip clearance flow. The effects that have been observed emphasize both the three-dimensional nature of the flow within compressor blade passages, and the importance of the flow in the endwall regions in determining the overall compressor performance. Author

**A90-23351**

### **MATHEMATICAL MODEL OF TURBOPROP ENGINE BEHAVIOUR**

JAROSLAV DOLEZAL, ZDENEK SCHINDLER, JIRI FIDLER (Ceskoslovenska Akademie Ved, Ustav Teorie Informace a Automatizace, Prague, Czechoslovakia), and OLDRICH MATOUSEK (Vyzkumny a Zkusebni Letecky Ustav, Prague, Czechoslovakia) Zprava VZLU, no. Z-59, 1989, p. 1-22. refs Copyright

The operation of a turboprop aircraft engine is analyzed by means of numerical simulations. The derivation of the mathematical model is explained; the approach used to incorporate experimental data is described; the solution of the resulting system of nonlinear algebraic inequalities by mathematical-programming methods is outlined; and the numerical implementation in FORTRAN is briefly characterized. Typical results are presented in graphs, and the model is shown to reproduce the steady-state behavior of a given engine under prescribed environmental and operating conditions. T.K.

**A90-23354**

### **THE FAST-RESPONSE REQUIREMENT OF POWERPLANT THRUST IN THE SET OF ENGINEERING AND ECONOMIC CRITERIA OF AN AIRCRAFT [POZADAVEK RYCHLE ODEZVY TAHU POHONU V KOMPLEXU TECHNICKOEKONOMICKYCH KRITERII LETADLA]**

BOHUSLAV RIHA Zpravodaj VZLU (ISSN 0044-5355), no. 4, 1989, p. 203-208. In Czech. refs Copyright

The complete utilization of the automation capabilities of a modern aircraft depends on the rate of change of powerplant thrust. The paper presents a brief survey of the main engineering and economic criteria to be observed when seeking the most advantageous compromise solutions for the powerplant with inclusion of the criterion of fast thrust response. B.J.

**A90-23405**

### **DISSIPATION THRUST LOSSES DUE TO DISTORTIONS OF THE JET NOZZLE PROFILE [POTERI TIAGI NA RASSEIANIE IZ-ZA ISKAZHENII KONFURA REAKTIVNOGO SOPLA]**

A. A. SERGIENKO Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 4, 1989, p. 15-18. In Russian. refs Copyright

The problem considered here concerns the effect of supersonic nozzle distortions due to tolerances, deformations, and heating on the thrust loss of the jet engine. The problem is solved on the basis of an analysis of expressions for the first and second thrust functional variations using an approximation whereby the change of pressure depends on the wall angle only. A formula is presented for calculating dissipation thrust losses due to distortions of the supersonic part of the nozzle. V.L.

**A90-23407**

### **A STUDY OF THE WORKING PROCESS AND LOSSES IN ANNULAR TURBINE NOZZLE CASCADES WITH A LOW CONTRACTION RATIO [ISSLEDOVANIE RABOCHEGO PROTSESSA I POTER' V KOL'TSEVYKH SOPLOVYKH TURBINNYKH RESHETKAKH PONIZHENNOI KONFUZORNOSTI]**

I. V. AFANAS'EV, O. N. EMIN, V. I. KUZNETSOV, and A. K. SITNIKOV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 4, 1989, p. 28-30. In Russian. refs Copyright

Experimental and analytical data are presented on the operation of low-contraction nozzle cascades that are typically used in the fan turbines of high-temperature bypass engines with relatively small bypass ratios. The results presented here demonstrate the possibility of using generalized empirical relations, obtained for plane cascades, for the rough estimation of profile and secondary losses, with three-dimensional flow contraction ratios substituted into these relations. V.L.

A90-23409

**AN EXPERIMENTAL STUDY OF THE GASDYNAMIC CHARACTERISTICS OF ANNULAR NOZZLE CASCADES WITH SMALL FLOW EXIT ANGLES [EKSPERIMENTAL'NOE ISSLEDOVANIE GAZODINAMICHESKIKH KHKARAKTERISTIK KOL'TSEVYKH RESHETOK SOPLOVYKH APPARATOV S MALYMI UGLAMI VYKHODA POTOKA]**

L. S. GRINKRUG, I. I. KIRILLOV, O. E. KUPRIANOV, and V. A. RASSOKHIN. *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 35-39. In Russian. refs

Copyright

Results of an experimental study of annular nozzle cascades with small flow exit angles, designed for low-flow-rate turbines with a relatively large rotor blade pitch, are reported. Optimal conditions for the delivery of the working medium are determined. Loss estimates are presented for three different nozzle cascades.

V.L.

A90-23410

**OPTIMAL SELECTION OF THE PARAMETERS TO BE MEASURED DURING THE IDENTIFICATION OF GAS TURBINE ENGINES. I - PROBLEM STATEMENT [OPTIMAL'NYI VYBOR IZMERIAEMYKH PARAMETROV PRI IDENTIFIKATSII GTD. I - POSTANOVKA ZADACHI]**

S. V. EPIFANOV, D. F. SIMBIRSKII, and S. A. KAPLUN. *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 39-44. In Russian. refs

Copyright

A method is proposed for the optimal selection of measured parameters and other significant experimental factors for the parametric identification of gas turbine assemblies in a full-scale engine system. The approach based on the use of a limited number of measured parameters of the gasdynamic path together with mathematical model is briefly reviewed, and some problems associated with this approach are identified. It is then shown how these difficulties can be solved by using a special parameterization procedure.

V.L.

A90-23412

**ESTIMATION OF THE EFFICIENCY OF A RAMJET ENGINE WITH A THERMOCOMPRESSOR USING FUEL CONVERSION PRODUCTS [K OTSENKE EFEKTIVNOSTI PYRD S GAZOVYM TEPLOVYM KOMPRESSOROM NA PRODUKTAKH KONVERSI TOPLIVA]**

D. A. MUNSHTUKOV, P. P. KOSTENKO, and L. I. OTRISHKO. *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 47-50. In Russian.

Copyright

The thermogasdynamic effect in a gas thermocompressor is examined, and prospects for its use in ramjets are discussed. In particular, attention is given to the start-up characteristics of a ramjet equipped with a gas thermocompressor. Results of a thermogasdynamic analysis are presented for a thermocompressor-equipped ramjet with recirculation of fuel conversion products.

V.L.

A90-23417

**A PARAMETRIC OPTIMIZATION ALGORITHM FOR THE ELECTRICAL DISTRIBUTION CIRCUITS OF CIVIL AIRCRAFT [ALGORITM PARAMETRICHESKOI OPTIMIZATSII ELEKTRICHESKIKH RASPREDELITEL'NYKH SETEI VOZDUSHNYKH SUDOV GRAZHDANSKOI AVIATSII]**

V. I. KRIVENTSEV, V. V. DROZDOV, and A. A. KONDRASHOV. *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 67-71. In Russian.

Copyright

An algorithm for the parametric optimization of the electric power distribution systems of civil aircraft is proposed which is based on the recursion relation method. This approach makes it possible to distribute, in a uniform manner, voltage losses in different parts of the electrical circuit. The efficiency of the algorithm is demonstrated by using it to calculate a real aircraft power distribution system.

V.L.

A90-23425

**EFFECT OF THE CONTROL OF TURBOCOMPRESSOR GUIDE VANES ON THE THROTTLE CHARACTERISTICS OF A BYPASS ENGINE [VLIANIE UPRAVLENIIA NAPRAVLIAIUSHCHIMI LOPATKAMI TURBOKOMPRESSORA NA DROSSEL'NYE KHKARAKTERISTIKI DVUKHKONTURNOGO DVIGATELIA]**

I. N. EGOROV, I. A. EFIMOV, A. M. IVANOV, and V. N. FOMIN. *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 87-89. In Russian. refs

Copyright

The objective of the study was to determine a vane ring control law that would minimize the flow rate under off-design conditions, with no allowance made for the effect of the air scoop and the nozzle. The vane ring characteristics of the compressor were calculated on the basis of an analysis and statistical processing of experimental data obtained for axial-flow stages. The stability margin of the compressor cascades was maintained by using a controlled mixer. The effect of a fully controllable compressor on the throttle characteristics of a two-shaft bypass engine is evaluated.

V.L.

A90-23430

**A METHOD FOR THE COMPUTER-AIDED HYDRAULIC ANALYSIS OF THE TURBINE COOLING SYSTEMS OF AVIATION GAS TURBINE ENGINES [METODIKA GIDRAVLICHESKOGO RASCHETA NA EVM SISTEM OKHLAZHDENIIA TURBIN AVIATSIONNYKH GTD]**

B. V. BARANOVSKII and B. M. KONIUKHOV. *Aviatsionnaia Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 100-102. In Russian.

Copyright

A procedure for the computer-aided hydraulic analysis of turbine cooling systems is proposed whereby a complex hydraulic network is partitioned into a series of simple units. A flow rate balance condition is then obtained for these simple units. The order of the system of equations describing the balance condition equals the number of units for which pressures have been specified. Since the order of the system is equal to the number of the unknowns, the system is always solvable.

V.L.

N90-15104 Council for National Academic Awards (England).

**A STUDY OF VARIABLE GEOMETRY IN ADVANCED GAS TURBINES Ph.D. Thesis**

J. E. A. ROY-AIKINS 1988 226 p

Avail: Univ. Microfilms Order No. BRDX85735

The loss of performance of a gas turbine engine at off-design is primarily due to the rapid drop of the major cycle performance parameters with decrease in power and this may be aggravated by poor component performance. More and more stringent requirements are being put on the performance demanded from gas turbines and if future engines are to exhibit performances superior to those of present day engines, then a means must be found of controlling engine cycle such that the lapse rate of the major cycle parameters with power is reduced. In certain applications, it may be desirable to vary engine cycle with operating conditions in an attempt to re-optimize performance. Variable geometry in key engine components offers the advantage of either improving the internal performance of a component or rematching engine cycle to alter the flow-temperature-pressure relationships. Either method has the potential to improve engine performance. The program was used to study the performance of a number of cycles incorporating variable geometry and it was concluded that variable geometry can significantly improve the off-design performance of gas turbines.

Dissert. Abstr.

N90-15105# Florida Univ., Gainesville. Dept. of Environmental Engineering Sciences.

**DESIGN AND CALIBRATION OF AN IN-STACK, LOW-PRESSURE IMPACTOR Final Report, Jan. 1985 - Oct. 1987**

D. A. LUNDGREN and R. W. VANDERPOOL Mar. 1989 131 p (Contract F08635-83-C-0136)

## 07 AIRCRAFT PROPULSION AND POWER

(AD-A213531; AFESC/ESL-TR-88-31) Avail: NTIS HC A07/MF A01 CSCL 21/5

The purpose was to design, fabricate, calibrate, and field test a low-pressure impactor for sampling and size classifying particulate exhaust from jet engine test cells. All aspects of the effort are covered through an actual field test on a J79 type engine exhaust. A computer code for user prediction of impactor stage outputs is included as well as design drawings for impactor fabrication.

GRA

**N90-15106#** Battelle Columbus Labs., OH.  
**CHARACTERIZATION OF CHEMICALS ON ENGINE EXHAUST PARTICLES Final Report, Sep. 1986 - Dec. 1987**  
M. R. KUHLMAN and J. C. CHUANG Jun. 1989 116 p  
(Contract F08635-85-C-0122; AF PROJ. 1900)  
(AD-A213566; AFESC/ESL-TR-88-50) Avail: NTIS HC A06/MF A01 CSCL 24/1

The objective was to characterize particulate-bound chemicals emitted from military aircraft, both as they are emitted and as the exhaust ages. Three Air Force turbine engines (TF33-P3, TF33-P7, and J79C) were examined, using engine test cells at Tinker AFB, OK. Emissions were collected at power settings of idle, 30 percent, 75 percent, and injected into smog chambers for subsequent aging. Samples were collected from these chambers periodically during the photochemical experiments to permit measurements of the vapor phase and particle associated photochemical experiments to permit measurements of the vapor phase and particle associated polycyclic aromatic hydrocarbon (PAH) and derivatives under experimental conditions. Throughout the course of the experiments, measurements of the concentrations of total hydrocarbons, NO, NO<sub>x</sub>, and O<sub>3</sub> were made. The samples collected on filter and sorbent media were returned to the laboratory for extraction and analysis by gas chromatography/mass spectrometry (GC/MS) to determine masses of specific target compounds collected. The time profiles of these compounds are presented for the various engines, operating powers, sunlight levels, and photochemical reactivities examines.

GRA

**N90-15107#** Pratt and Whitney Aircraft, West Palm Beach, FL. Advanced Engineering Div.

**THERMAL MECHANICAL FATIGUE OF COATED BLADE MATERIALS Final Report, 1 Aug. 1984 - 30 Sep. 1988**

J. E. HEINE, J. R. WARREN, and B. A. COWLES 27 Jun. 1989 216 p

(Contract F33615-84-C-5027)

(AD-A214258; PW/FL/FR-20505; WRDC-TR-89-4027) Avail: NTIS HC A10/MF A02 CSCL 21/5

A model capable of predicting thermal mechanical fatigue (TMF) crack initiation and propagation in coated advanced blade materials, with emphasis on crack initiation, was developed and demonstrated. The experimental program included isothermal baseline and TMF tests on one alloy and two coating materials to evaluate the effects of mean stress, frequency, hold periods, and maximum temperature on the TMF life of a coated system. Task 1, Definition of TMF Conditions, was completed using the results of a separately funded program evaluating current and advanced airfoil conditions. Task 2, Alloy/Coating Selection and Isothermal Properties, generated monotonic data for uncoated PWA 1480, freestanding PWA 276 overlay coating, and PWA 275 aluminide coating.

GRA

**N90-15918#** Department of the Air Force, Washington, DC.

**EXTERNALLY VAPORIZING SYSTEM FOR TURBINE COMBUSTOR Patent**

CLIFFORD C. GLEASON, inventor (to AF) and EDWARD E. EKSTEDT, inventor (to AF) 13 Jun. 1989 5 p Filed 10 Sep. 1986 Supersedes US-Patent-Appl-SN-905439

(AD-D014284; US-PATENT-4,838,029;

US-PATENT-APPL-SN-905439) Avail: US Patent and Trademark Office CSCL 21/5

The present invention relates to turbine engines, and, in particular, relates to a combustor therein. The present invention is directed toward providing a combustor in which the undesirable characteristics of prior liquid fuel systems are overcome in light of

the advantages of a purely gaseous system. The externally vaporizing system of the present invention incorporates an auxiliary burner which is supplied with compressor discharge air at a rate which is regulated to the main fuel flow rate. The auxiliary burner is operated at approximately stoichiometric fuel-air-ratio, in order to provide very-hot, nearly-inert gases for vaporizing the main fuel supply. The main fuel is sprayed in the auxiliary burner exit gas stream where rapid mixing and evaporation occur. The resulting vaporized fuel/inert gas mixture (at about 800 F, preferably) is then ducted and distributed to the individual main combustor fuel injectors where it is injected into the premixing ducts.

GRA

**N90-15919#** Royal Aerospace Establishment, Farnborough (England).

**PERFORMANCE OF A HIGHLY-LOADED HP COMPRESSOR**

W. J. CALVERT, R. B. GINDER, I. R. I. MCKENZIE, and D. J. WAY Feb. 1989 11 p Presented at the 34th International Gas Turbine and Aeroengine Congress and Exposition, Toronto, Ontario, 5-8 Jun. 1989

(RAE-TM-P-1149; BR110401; ETN-90-96126) Copyright Avail: NTIS HC A03/MF A01

A 4 stage axial research compressor, representative of the rearmost stages of a highly loaded military or civil compression system, is designed and tested. It is a large scale compressor, with extended inter-row gaps, to facilitate the acquisition of detailed aerodynamic data. Its design pressure ratio is exceeded by a factor of 4.0, and a peak polytropic efficiency at design speed of 89 percent is obtained. The flow profiles obtained from area traversing at stator exits are presented and discussed. The performance is measured and an inviscid-viscous blade-to-blade method, is incorporated.

ESA

**N90-15920#** Royal Aerospace Establishment, Farnborough (England). Propulsion Dept.

**AERODYNAMIC AND HEAT TRANSFER MEASUREMENTS ON BLADING FOR A HIGH RIM-SPEED TRANSONIC TURBINE**

R. C. KINGCOMBE, S. P. HARASGAMA, N. P. LEVER SUCH, and E. T. WEDLAKE Mar. 1989 11 p Presented at the 34th ASME International Gas Turbine and Aeroengine Congress, Toronto, Ontario, 5-8 Jun. 1989

(RAE-TM-P-1151; BR110400; ETN-90-96127) Copyright Avail: NTIS HC A03/MF A01

A high rim speed turbine incorporating 3-D features is designed and tested. The cold flow turbine testing, with performance measurements, rotor exit traversing and surface static pressure measurements on the vane and rotor, is performed. The vane is tested in annular cascade on the isentropic light piston cascade. Surface heat transfer measurements on the vanes and endwalls and aerodynamic information are given. The data is compared with design predictions and the reasons for the differences observed are explored.

ESA

**N90-15921** Royal Aerospace Establishment, Farnborough (England).

**CYCLE ANALYSIS FOR HELICOPTER GAS TURBINE ENGINES**

A. D. BEWLEY Apr. 1989 12 p Presented at the 34th ASME International Gas Turbine and Aeroengine Congress and Exposition, Toronto, Ontario, 5-8 Jun. 1989

(RAE-TM-P-1154; BR110402; ETN-90-96128) Copyright Avail: NTIS HC A03/MF A01

The performance potential of a 1000 kW gas turbine engine is determined in terms of specific fuel consumption and specific power. Compressor and turbine efficiencies are assumed size dependent. The cycle temperature is determined from the material capability and cooling technology available. Heat exchanger cycle engines for helicopters are considered. As cycle temperatures increase, a low pressure ratio engine with a single stage gas generator turbine provides the most cost effective solution. The heat exchanger cycle is attractive only for those helicopter missions where endurance or fuel conservation is the dominating requirement.

ESA



**N90-15922#** Royal Aerospace Establishment, Farnborough (England).

**A UK PERSPECTIVE ON THE UNIFORM ENGINE TEST PROGRAMME**

M. HOLMES, A. R. OSBORN, and J. C. ASCOUGH Jun. 1989 26 p Presented at the 1989 European Propulsion Forum on Modern Techniques and Developments in Engine and Component Testing, Bath, England, 19-21 Apr. 1989; sponsored by the Royal Aeronautical Society, AAAF, and DGLR (RAE-TM-P-1172; BR110949; ETN-90-96129) Copyright Avail: NTIS HC A03/MF A01

The uniform engine test program and the test results are given. The program provides the opportunity for aeroengine test facilities in Europe and North America for the evaluation of the test procedures and methods of analysis. It is achieved by testing the same engines over an agreed range of operating conditions. Nozzle coefficients are used as a basis for comparing gross thrust and airflow measurements. The differences in some of the other performance parameters are compared with the predicted precision and bias errors. ESA

**N90-15923\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**ASSESSMENT OF WORM GEARING FOR HELICOPTER TRANSMISSIONS**

LEV CHAIKO Jan. 1990 16 p Prepared in cooperation with Army Aviation Systems Command, Cleveland, OH (Contract DA PROJ. 1L1-61102-AH-45) (NASA-TM-102441; E-5212; NAS 1.15:102441; AVSCOM-TM-89-C-010) Avail: NTIS HC A03/MF A01 CSCL 13/9

A high-efficiency hydrostatic worm gear drive for helicopter transmissions is assessed. The example given is for a large cargo helicopter with three 4000-kW engines and transmission reduction ratio of 110. Also contained are: an efficiency calculation, a description of the test stand for evaluating the feasibility of worm gear hydrostatic mesh, a weight calculation, and a comparison with conventional helicopter transmissions of the same power and transmission reduction ratio. Author

## 08

## AIRCRAFT STABILITY AND CONTROL

Includes aircraft handling qualities; piloting; flight controls; and autopilots.

**A90-21987#**

**A VARIABLE STRUCTURE SYSTEM (VSS) TO ROBUST CONTROL OF AIRCRAFT**

CHUNLIN SHEN, SUIJIANG ZHENG, and SHUXUN PAN (Nanjing Aeronautical Institute, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, Nov. 1989, p. A613-A618. In Chinese, with abstract in English. refs

When aircraft fly in large flight envelopes, it is often required that their control systems be robust. Here, variable structure system (VSS) theory is applied to the design of a flight control system. A general technique for scalar VSS CAD is suggested, and special attention is given to engineering applications. A numerical example is given and compared with original PD control by simulation. C.D.

**A90-22184\*#** California Inst. of Tech., Pasadena.

**APPLICATION OF DYNAMICAL SYSTEMS THEORY TO THE HIGH ANGLE OF ATTACK DYNAMICS OF THE F-14**

CRAIG C. JAHNKE and FRED E. C. CULICK (California Institute of Technology, Pasadena) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 20 p. Research supported by NASA and California Institute of Technology. refs (AIAA PAPER 90-0221) Copyright

Dynamical systems theory has been used to study the nonlinear dynamics of the F-14. An eight degree of freedom model that does not include the control system present in operational F-14s has been analyzed. The aerodynamic model, supplied by NASA, includes nonlinearities as functions of the angles of attack and sideslip, the rotation rate, and the elevator deflection. A continuation method has been used to calculate the steady states of the F-14 as continuous functions of the control surface deflections. Bifurcations of these steady states have been used to predict the onset of wing rock, spiral divergence, and jump phenomena which cause the aircraft to enter a spin. A simple feedback control system was designed to eliminate the wing rock and spiral divergence instabilities. The predictions were verified with numerical simulations. Author

**A90-23357**

**THE APPLICATION OF THE DISCRETE VORTEX METHOD IN AIRCRAFT DESIGN [APLIKACE MODELU DISKRETNICH VIRO PRI NAVRHU LETOUNU]**

VLADIMIR DANEK Zpravodaj VZLU (ISSN 0044-5355), no. 5, 1989, p. 273-276. In Czech. Copyright

A mathematical model based on the discrete vortex method is described, which makes it possible to calculate aerodynamic derivatives and kinematic quantities in a trimmed flight condition. On the basis of these quantities it is possible to determine the trimming-induced drag of an aircraft. The mathematical model is suitable for the optimization of horizontal tailplane design with regard to the trimming-induced drag minimization. Author

**A90-23358**

**FLIGHT-MECHANICS TASKS IN SOLVING PROBLEMS OF ACTIVE CONTROL [ULOHY MECHANIKY LETU PRI RESENI PROBLEMATIKY AKTIVNIHO RIZENI]**

JINDRICH DEDEK Zpravodaj VZLU (ISSN 0044-5355), no. 5, 1989, p. 277-281. In Czech. Copyright

Some approaches to solving active-control problems are presented. An example of active control system design for lateral stability augmentation is presented by way of illustration. B.J.

**A90-23359**

**COMPUTER-AIDED SIMULATION OF AIRCRAFT MOTION INCLUDING NONLINEARITIES IN AERODYNAMIC-COEFFICIENT RELATIONSHIPS [POCITACOVA SIMULACE POHYBU LETOUNU SE ZAHRNUTIM Nelinearit v Zavislostech Aerodynamickych Soucinitelu]**

JIRI KVARDA Zpravodaj VZLU (ISSN 0044-5355), no. 5, 1989, p. 283-286. In Czech. Copyright

This paper presents a method for the numerical solution of the differential equations of aircraft motion, which makes it possible to compute the motion time history in the case of significant nonlinearities in aerodynamic-coefficient relationships. An approach for the numerical modeling of the aerodynamic-coefficient relationships and a numerical method for solving the initial value problem of the system of ordinary differential equations are suggested. The method is demonstrated on the example of the time history simulation of the longitudinal motion of a training aircraft. Author

**A90-23478\*** California Univ., Davis.

**AN APPLICATION OF GENERALIZED PREDICTIVE CONTROL TO ROTORCRAFT TERRAIN-FOLLOWING FLIGHT**

RONALD A. HESS and YOON C. JUNG (California, University, Davis) (IEEE, International Conference on Systems, Man, and Cybernetics, Beijing and Shenyang, People's Republic of China, Aug. 8-12, 1988) IEEE Transactions on Systems, Man, and Cybernetics (ISSN 0018-9472), vol. 19, Sept.-Oct. 1989, p. 955-962. refs (Contract NAG2-221) Copyright

Generalized predictive control (GPC) describes an algorithm for the control of dynamic systems in which a control input is generated which minimizes a quadratic cost function consisting of a weighted sum of errors between desired and predicted future system output and future predicted control increments. The output predictions are obtained from an internal model of the plant dynamics. The GPC algorithm is first applied to a simplified rotorcraft terrain-following problem, and GPC performance is compared to that of a conventional compensatory automatic system in terms of flight-path following, control activity, and control law implementation. Next, more realistic vehicle dynamics are utilized, and the GPC algorithm is applied to simultaneous terrain following and velocity control in the presence of atmospheric disturbances and errors in the internal model of the vehicle. The online computational and sensing requirements for implementing the GPC algorithm are minimal. Its use for manual control models appears promising. I.E.

**N90-15050#** Aerospatiale, Toulouse (France).

### HOW TO FLY WINDSHEAR USING THE FLY-BY-WIRE CONCEPT

J. L. BONAFE *In* AGARD, Flight in Adverse Environmental Conditions 16 p Sep. 1989

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In the past three years, Aerospatiale has developed windshear warning and guidance systems for the A310 and the A300-600; these systems are either newly designed or constructed around the Speed Reference System designed for the A300 and exploited in revenue flight since 1975; they are in accordance with certification rules; and were installed on board the A300-600 since April 1988. Aerospatiale's warning and guidance philosophy regarding the conventional AIRBUS is presented, then the fly-by-wire concept analyzed. The fly-by-wire concept improves the general aircraft situation, and advantage is taken of these new capabilities in the warning and guidance elaboration. Systems will be adapted for the A320 certified and installed onboard in the near future. Author

**N90-15051#** Instituto Superior Tecnico, Lisbon (Portugal).

### A PITCH CONTROL LAW FOR COMPENSATION OF THE PHUGOID MODE INDUCED BY WINDSHEARS

I. M. B. C. CAMPOS, A. J. N. M. AGULAR, and J. R. C. AZINHEIRA *In* AGARD, Flight in Adverse Environmental Conditions 13 p Sep. 1989

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In a previous paper the development of a flight test facility in Portugal was described. This reference mentioned briefly some of the research projects for which the facility would be initially used, including among other studies in non-linear pitch stability and aircraft response to atmospheric disturbances. The purpose is to discuss in more detail the flight mechanical theory which underlies these research projects: the comparison of theory with flight test data will have to await the availability of the CASA 212 Aviocar aircraft, which is at present already has all sensors installed but is still undergoing final check-out of instrumentation describing pitch stability for flight along a constant glide slope, taking into account the phugoid but neglecting the short period mode. The model is solved to find pitch control laws for two problems: the non-linear problem of keeping an aircraft on a constant glide slope in still air starting from an arbitrary initial velocity, possibly for removed from the steady flight speeds; and the linearized problem of keeping an aircraft on a constant glide slope in the presence of longitudinal and vertical winds of peak velocity up to 30 percent of the aircraft velocity, which provide a representation of a moderately strong windshear. Author

**N90-15053#** Aeronautica Macchi S.p.A., Varese (Italy). Flight Mechanics and Automatic Control Dept.

### CANARD VERSUS AFT-TAIL RIDE QUALITIES PERFORMANCE AND PILOT COMMAND RESPONSE

L. V. CIOFFI and L. MANGIACASALE *In* AGARD, Flight in Adverse Environmental Conditions 13 p Sep. 1989

Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

A comparison between a Close-Coupled configuration and a Close-Coupled Tail configuration was developed in terms of ride qualities and pilot command response in turbulence. Parameters of the study are the mass factor of the airplane, the static stability, and the sign of the trailing-edge flap effectiveness (only for the aft-tail airplane). The known ride quality criteria are used in order to assess the flying qualities of the airplane. Interesting conclusions are derived in terms of configuration sensitivity and attenuation capabilities. Further research is needed in order to add structural flexibility and unsteady aerodynamics to the design model. Pilot command responses are in agreement with the current flying qualities parameters, but a special purpose control law has to be designed for good tracking in presence of discrete gusts. Author

**N90-15054#** Messerschmitt-Boelkow-Blohm G.m.b.H., Hamburg (Germany, F.R.). Dynamic Dept.

### THE INTERFERENCE OF FLIGHTMECHANICAL CONTROL LAWS WITH THOSE OF LOAD ALLEVIATION AND ITS INFLUENCE ON STRUCTURAL DESIGN

M. MOLZOW and R. MOEBEST *In* AGARD, Flight in Adverse Environmental Conditions 20 p Sep. 1989

Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Today modern A/C designs use fly-by-wire together with control laws to make the A/C comfortable for handling in service. In addition, this implies an attractive chance for a lot of protections and limitations with the aim to improve handling quality characteristics or to protect the aircraft against overloading. Examples are: overspeed protection; load factor protection; and stall protection. Another chance is the implementation of Load Alleviation Functions (LAF). To optimize the overall A/C design a close cooperation between the different disciplines like: systems, handling quality, aerodynamics, loads, and stressing is needed, not to cancel the benefits in one discipline by handicaps or additional weight in others. The different problems, which have carefully to be watched in relation of interference to each other to reach an overall optimum are described. Author

**N90-15055#** Oklahoma State Univ., Stillwater. Dept. of Mechanical and Aerospace Engineering.

### TURBULENCE EFFECTS OF AIRCRAFT FLIGHT DYNAMICS AND CONTROL

ROBERT L. SWAIM *In* AGARD, Flight in Adverse Environmental Conditions 9 p Sep. 1989

Copyright Avail: NTIS HC A17/MF A03; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

Design of aircraft flight control systems requires consideration of many factors including maneuvering, ride and handling qualities, stability augmentation, and control power requirements as well as several others. All the mentioned factors, however, are strongly influenced by the atmospheric turbulence environment through which the aircraft must fly. A unified analytical design method is described which systematically accounts for three-component gust velocity spatial distribution effects, handling qualities in terms of needed closed-loop stability augmentation systems, and the maneuvering and stabilization three-axis control power required. These factors are all interrelated. State variable formulations of modern system theory are used for the aircraft and turbulence dynamic models and in stability augmentation system synthesis. Both homogeneous and heterogeneous turbulence are considered. Homogeneous models are described in a statistical sense. Heterogeneous turbulence is discrete due to vortex patterns

generated by obstacles such as trees, buildings, or mountains, and is known to result in aircraft upsets and structural failure.

Author

**N90-15056#** Dornier-Werke G.m.b.H., Friedrichshafen (Germany, F.R.).

**ACTIVE CONTROL SYSTEM FOR GUST LOAD ALLEVIATION AND STRUCTURAL DAMPING**

HARTMUT BOEHRET and JOACHIM WINTER /in AGARD, Flight in Adverse Environmental Conditions 11 p Sep. 1989

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Based on the Do-228 regional airliner, the improvement in passenger comfort provided by the gust load alleviation system Open Loop Gust Alleviation (OLGA) under adverse weather conditions is shown. The problem of excited structural vibrations is solved with an active structural damper, which eliminates the adverse effect of the gust load alleviation system on structural vibrations and, additionally, diminishes their excitation by maneuvers and gust loads.

Author

**N90-15057#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Flugmechanik.

**AIRCRAFT RESPONSE AND PILOT BEHAVIOUR DURING A WAKE VORTEX ENCOUNTER PERPENDICULAR TO THE VORTEX AXIS**

REINHARD KOENIG /in AGARD, Flight in Adverse Environmental Conditions 18 p Sep. 1989

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Vortex systems can be hazardous to trailing aircraft which encounter them in flight. The greatest hazard occurs in areas where aircraft from a wide range of classes operate and where the flight paths are close to the ground. Upwash velocities induced by the wake vortices can be equivalent to the design gust velocities. Furthermore different types of hazardous effects exist when encountering the vortex system, such as imposed rolling and pitching moments, a loss of rate of climb, a loss of altitude and structural loads. Aircraft response and pilot behavior during takeoff are described when a wake vortex is encountered perpendicular to the vortex axis. The aircraft response is calculated by nonlinear digital simulation with a mathematical model of a wake vortex system close to the ground. This real-time vortex model is also used in the Boeing B-737 simulator of Deutsche Lufthansa in order to examine the pilot behavior. Close to the ground, the wake vortex system induces additional horizontal velocities. There exists a critical flight path where very large g-loads are induced by vertical and horizontal vortex velocities and normal vertical acceleration shortly after takeoff. Often the pilot will attempt to counteract these g-loads, but this produces only a small effect.

Author

**N90-15108\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**RELATIVE MERITS OF REACTIVE AND FORWARD-LOOK DETECTION FOR WIND-SHEAR ENCOUNTERS DURING LANDING APPROACH FOR VARIOUS MICROBURST ESCAPE STRATEGIES**

DAVID A. HINTON Washington Feb. 1990 24 p Prepared in cooperation with DOE, Washington, DC

(NASA-TM-4158; L-16622; NAS 1.15:4158; DOT/FAA/DS-89/35) Avail: NTIS HC A03/MF A01 CSCL 01/3

The goal was to quantify the benefits of airborne forward-look windshear detection and to develop and test a candidate set of strategies for recovery from inadvertent microburst encounters during the landing approach, given the utilization of both reactive-only and forward-look windshear detection. Candidate strategies were developed and evaluated using a non-piloted simulation consisting of a simple point-mass performance model of a transport-category airplane flying through an analytical

microburst model. The results indicate that the factor which most strongly effects a microburst recovery is the time at which the recovery is initiated. Forward-look alerts given 10 seconds prior to microburst entry permitted recoveries to be made with negligible altitude loss. The results also show that no single microburst scenario can be used to evaluate the relative merits of various recovery strategies. The type of alert used to initiate the recovery (reactive or forward-look) and the altitude of the microburst encounter had an effect on the type of recovery strategy that performed best. These factors may have serious implications for the design and certification of windshear systems.

Author

**N90-15110\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

**GUIDANCE ANALYSIS OF THE AEROGlide PLANE CHANGE MANEUVER AS A TURNING POINT PROBLEM**

CHRISTOPHER GRACEY Dec. 1989 29 p

(NASA-TM-101639; NAS 1.15:101639) Avail: NTIS HC A03/MF A01 CSCL 01/3

The development of guidance approximations for the atmospheric (aeroglide) portion of the minimum fuel, orbital plane change, trajectory optimization problem is described. Asymptotic methods are used to reduce the two point, boundary value, optimization problem to a turning point problem from the bank angle control. The turning point problem solution, which yields an approximate optimal control policy, is given in terms of parabolic cylinder functions, which are tabulated, and integral expressions, which must be numerically computed. Comparisons of the former, over their region of validity, with optimal control solutions show good qualitative agreement. Additional work and analysis is needed to compute the guidance approximation work.

Author

**N90-15111\*#** Boeing Commercial Airplane Co., Seattle, WA.

**FLY-BY-LIGHT FLIGHT CONTROL SYSTEM TECHNOLOGY DEVELOPMENT PLAN Final Report**

A. CHAKRAVARTY, J. W. BERWICK, D. M. GRIFFITH, S. E. MARSTON, and R. L. NORTON Jan. 1990 49 p

(Contract NAS1-18027)

(NASA-CR-181953; NAS 1.26:181953) Avail: NTIS HC A03/MF A01 CSCL 01/3

The results of a four-month, phased effort to develop a Fly-by-Light Technology Development Plan are documented. The technical shortfalls for each phase were identified and a development plan to bridge the technical gap was developed. The production configuration was defined for a 757-type airplane, but it is suggested that the demonstration flight be conducted on the NASA Transport Systems Research Vehicle. The modifications required and verification and validation issues are delineated in this report. A detailed schedule for the phased introduction of fly-by-light system components has been generated. It is concluded that a fiber-optics program would contribute significantly toward developing the required state of readiness that will make a fly-by-light control system not only cost effective but reliable without mitigating the weight and high-energy radio frequency related benefits.

Author

**N90-15112\*#** National Aeronautics and Space Administration, Lewis Research Center, Cleveland, OH.

**ADVANCED DETECTION, ISOLATION, AND ACCOMMODATION OF SENSOR FAILURES IN TURBOFAN ENGINES: REAL-TIME MICROCOMPUTER IMPLEMENTATION**

JOHN C. DELAAT and WALTER C. MERRILL Washington Feb. 1990 28 p

(NASA-TP-2925; E-4391; NAS 1.60:2925) Avail: NTIS HC A03/MF A01 CSCL 01/3

The objective of the Advanced Detection, Isolation, and Accommodation Program is to improve the overall demonstrated reliability of digital electronic control systems for turbine engines. For this purpose, an algorithm was developed which detects, isolates, and accommodates sensor failures by using analytical redundancy. The performance of this algorithm was evaluated on a real time engine simulation and was demonstrated on a full scale F100 turbofan engine. The real time implementation of the

algorithm is described. The implementation used state-of-the-art microprocessor hardware and software, including parallel processing and high order language programming. Author

**N90-15113#** Virginia Univ., Charlottesville. Dept. of Mechanical and Aerospace Engineering.

### **ADAPTIVE CONTROL OF HELICOPTER VIBRATIONS VIA THE IMPULSE RESPONSE METHOD Final Report, 1 Jun. 1986 - 31 May 1989**

CARL R. KNOSPE, J. K. HAVILAND, and W. D. PILKEY Sep. 1989 77 p

(Contract DAAL03-86-G-0043)

(AD-A213728; UVA525167/MAE90/101; ARO-23761.2-EG-F)

Avail: NTIS HC A05/MF A01 CSCL 01/2

An adaptive blade control algorithm for helicopter vibration reduction is developed as an application of an impulse response control method. The method is based on an impulse response formulation which is applicable to any linear system with periodic dynamics. In the investigation of adaptive helicopter vibration control presented, a vertical-axis-only plant is simulated by a model composed of an impulse response matrix and an uncontrolled vibration vector. The adaptive control is implemented by a regulator composed of an estimator and a controller. The model parameters are identified by either Kalman or batch Weighted Least Squares (WLS) filtering in either global or local form. The resulting estimates are used in an optimal control law obtained by the minimization of a constrained, single-step, quadratic performance function. Four control laws are derived: global certainty-equivalent, local certainty equivalent, global cautious, and local cautious. The filters derived are examined in open loop simulations to determine their identification capabilities independent of the control feedback. Two levels of open loop control variation are used to evaluate estimation performance with constant and time-varying plants. The Kalman filters are found to produce lower estimate errors than the WLS filters. GRA

**N90-15924#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Guidance and Control Panel.

### **GUIDANCE AND CONTROL OF UNMANNED AIR VEHICLES**

Aug. 1989 191 p In ENGLISH and FRENCH Symposium held in San Francisco, CA, 4-7 Oct. 1988

(AGARD-CP-436; ISBN-92-835-0523-9) Copyright Avail: NTIS HC A09/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The following topics were discussed: operational concepts, requirements and systems, vehicle guidance and control, optical systems, systems external to the vehicle, and evaluation and test.

**N90-15925#** Ecole Nationale de l'Aeronautique et de l'Espace, Toulouse (France).

### **SYNTHESIS OF CONTROL LAW, ON A RPV, IN ORDER TO MINIMIZE THE NUMBER OF SENSORS**

JEAN-LUC BOIFFIER In AGARD, Guidance and Control of Unmanned Air Vehicles 17 p Aug. 1989 Sponsored by ENSAE and Centre d'Etudes et de Recherche, Toulouse, France

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Two 25 kg Remotely Piloted Vehicles (RPVs) were built and the capabilities in flight were demonstrated. This RPV is equipped with a digital computer which enables the plane to be under automatic control for a sea skimmer flight. A 50 kg RPV project, with a 20 kg payload under 300 W, for a flight of 2500 m high and 6 hour flying time is now being developed. The first flight is planned for 1990. These specifications need to pay special attention to the weights. One kilo represents 15 percent of the performance. The airplane configuration was optimized to minimize the weights of the airframe and fuel. Optimal wing area, aspect ratio, area ratio between front and rear lifting surfaces, were found. The avionics systems were treated with the same effort. In particular, control laws were studied in order to reduce the number of sensors needed to control and guide the plane. A method is described for

avoiding the installation of a vertical gyroscope, which is a heavy sensor, for this kind of RPV. The lighter the plane is, the more this proposition is interesting. The plane and turbulence are described, and the automatic lateral control is presented. The following topics are approached: adjustment of the natural mode of the plane in order to reduce the sensitivity of the plane under the effect of turbulence, basic control law by LQ method, installation of wash-out filters on the measurement to avoid drift sensors effect, optimization of the wash-out frequency, and general performances with and without bank and heading angle measurement. Author

**N90-15926#** METEOR Costruzioni Aeronautiche ed Elettroniche S.p.A., Ronchi dei Legionari (Italy).

### **MIRACH 100 FLIGHT CONTROL SYSTEM**

ANES SBUELZ In AGARD, Guidance and Control of Unmanned Air Vehicles 17 p Aug. 1989

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The Mirach 100 air-vehicle is a multipurpose RPV-UMA, suited to intelligence missions of target recognition, acquisition, and identification up to 150 km. It is a high-subsonic speed, jet-powered drone having a ceiling altitude of 9000 m and 1 hour endurance. Different arrangements of the base air-vehicle allow higher altitudes or wider endurances according to the mission operational requirements. The flight control system of the Mirach 100 is mainly a compound of already tested in flight components. Autopilot function includes a full control system of stabilization on two axes, simply designed to improve reliability and safety of guidance. Mechanization is based on a simple analogic control circuit of the actuators that drive the control surfaces of the aircraft, stabilized through the vertical gyroscope feed-back; the gyroscope is installed in the air-vehicle fore structure. Guidance function includes a complete control system based on altitude, heading and velocity integrated in the flight controller which runs the whole aircraft, pay load included. Navigation function is based on a OMEGA/VLF receiver and navigator, suited to memorize a flight plan formed with up to 99 geographical points sequentially navigated, starting from any of it. From the computation a wind parameter is estimated which includes the on-board sensor errors, giving improved navigation performances even when the omega-receiver operates in marginal conditions. The drone is guided to follow the programmed flight plan. Complete avionics and aircraft itself were modeled on a computer for dynamic and static stability analysis and performance computations; the results obtained were compared with those recorded during the Mirach 100 test flights performed at the experimental range Salto di Quirra in Sardinia. Test flights gave excellent results about steering, guidance and navigation. The altitude and speed control were obtained with an accuracy that went far beyond the expectations, reaching the accuracy level of the sensor used in the testing program. Author

**N90-15938\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **A SURVEY OF NONUNIFORM INFLOW MODELS FOR ROTORCRAFT FLIGHT DYNAMICS AND CONTROL APPLICATIONS**

ROBERT T. N. CHEN Nov. 1989 65 p Presented at the 15th European Rotorcraft Forum, Amsterdam, Netherlands, 12-15 Sep. 1989

(NASA-TM-102219; A-89220; NAS 1.15:102219) Avail: NTIS HC A04/MF A01 CSCL 01/3

The results of a brief survey of nonuniform inflow models was summarized for the calculation of induced velocities at and near a lifting rotor in and out of ground effect. The survey, conducted from the perspective of flight dynamics and control applications, covers a spectrum of flight conditions including hover, vertical flight, and low-speed and high-speed forward flight, and reviews both static and dynamic aspects of the inflow. A primary emphasis is on the evaluation of various simple first harmonic inflow models developed over the years, in comparison with more sophisticated methods developed for use in performance and airload

computations. The results of correlation with several sets of test data obtained at the rotor out of ground effect indicate that the Pitt/Peters first harmonic inflow model works well overall. For inflow near the rotor or in ground effect, it is suggested that charts similar to those of Heyson/Katzoff and Castles/De Leeuw of NACA be produced using modern free-wake methods for use in flight dynamic analyses and simulations. Author

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## RESEARCH AND SUPPORT FACILITIES (AIR)

Includes airports, hangars and runways; aircraft repair and overhaul facilities; wind tunnels; shock tube facilities; and engine test blocks.

## A90-21035#

## PRELIMINARY TESTS OF A GUST GENERATOR IN THE ONERA S3CH TRANSONIC WIND TUNNEL

ERIC BRUNEL and HERVE CONSIGNY (ONERA, Chatillon-sous-Bagneux, France) (Supersonic Tunnel Association, Semi-Annual Meeting, 72nd, Princeton University, NJ, Oct. 3, 4, 1989) ONERA, TP no. 1989-171, 1989, 20 p. (ONERA, TP NO. 1989-171)

This paper presents the first results of an experimental study concerning a rotor-type gust generator that was carried out in the ONERA S3Ch transonic wind tunnel. Because of an underestimation of the necessary driving power, the initially planned test envelope was not fully covered. Available results show, however, that the proposed solution is capable of producing high frequency periodic cylindrical gusts of 0.1 to 1 deg amplitude, having a vertical homogeneity consistent with the size of models usually tested in this facility. Author

## A90-21047#

## CONDITIONAL SAMPLING [LE PRELEVEMENT CONDITIONNEL]

C. ARMAND and R. SELVAGGINI (ONERA, Modane, France) ONERA, TP no. 1989-187, 1989, 20 p. In French. (ONERA, TP NO. 1989-187)

A conditional sampling technique for processing data from wind-tunnel experiments is described and demonstrated. In this approach, error tolerances are established for the parameters defining the experimental conditions (PDECs), and both the PDECs and the parameters of experimental interest (PEIs) are monitored continuously. For the analysis, however, only PEI data from time points at which the PDECs are within the tolerances are selected. Data on full and half models of a civil transport aircraft, obtained using mechanical and electronic pressure sensors in the ONERA wind tunnel at Modane-Avrieux, are presented in extensive graphs and discussed. Significant improvements in data reliability are achieved by applying conditional sampling, without adverse effects on the tunnel experiment schedule or real-time computation performance. T.K.

## A90-21049#

## INSTRUMENTATION BEING DEVELOPED FOR THE ONERA F4 WIND TUNNEL [INSTRUMENTATION EN COURS DE DEVELOPPEMENT POUR LA SOUFFLERIE F4 DE L'ONERA]

A. GIRARD, A. BOUTIER, J. P. CHEVALLIER, and G. FRANCOIS (ONERA, Chatillon-sous-Bagneux, France) ONERA, TP no. 1989-189, 1989, 27 p. In French. refs (ONERA, TP NO. 1989-189)

The current development status of measurement instruments for the F4 hot-shot hypersonic wind tunnel being constructed at ONERA Fauga-Mauzac is surveyed. The principal elements include a schlieren photography system (with 500-mm-diameter mirrors mounted inside the evacuated test chamber) and a six-component balance with compensation for inertia. Also planned are electron-beam-induced fluorescence measurements of velocity,

chemical concentrations, and nitrogen vibrational and rotational temperatures; interferometric holography; high-rate IR thermography; and tunable-diode-laser spectroscopy. Diagrams, drawings, graphs, and tables of numerical data are provided. T.K.

## A90-21051#

## THE APPLICATION OF INFRARED THERMOGRAPHY TO THE MEASUREMENT OF HEAT FLUXES IN A WIND TUNNEL [APPLICATION DE LA THERMOGRAPHIE INFRAROUGE A LA MESURE DES FLUX THERMIQUES EN SOUFFLERIE]

D. BALAGEAS, D. BOSCHER, P. DELPECH, A. DEOM, J. FOURNIER (ONERA, Chatillon-sous-Bagneux, France) et al. ONERA, TP no. 1989-192, 1989, 20 p. In French. Research supported by DRET, CEA, and Matra, S.A. refs (ONERA, TP NO. 1989-192)

Advanced IR thermal imaging devices make possible the precise determination of unsteady surface-temperature fields. The combination of this technique with thermal simulation makes possible a quantitative determination of heat transfer coefficients at the walls of wind-tunnel models. Various thermography methods are discussed, including passive thermography (where the heating of the model is nonconvective) and stimulated thermography (where a moderate radiative flux is applied). Some practical measurement examples are presented, and the technical problems that have to be solved in this area are considered. Application to the heating of a wind-tunnel model in supersonic flow is discussed in detail. B.J.

## A90-21605#

## ANTENNA AND RADAR SIGNATURE TECHNOLOGY AT DORNIER

JOACHIM FLACKE, JOACHIM BOUKAMP, and WULF KOSCHEL Dornier Post (ISSN 0012-5563), no. 3, 1989, p. 16-20. Copyright

An aircraft radar signature-determination and radar antenna-testing facility has been constructed which simulates radar far-fields with excellent amplitude and phase homogeneity, and which allows high-resolution 'radar imaging' to be conducted by means of the inverse-SAR process. The test facility will be able to measure radiation diagrams, determine the characteristics of ground facility, aircraft and missile radomes; make radar cross-section determinations for a backscattering object from a variety of perspectives, ranges, and operating frequencies; and identify backscatter centers. O.C.

## A90-21628#

## ICAO AIRFIELD REFERENCE CODE [LOTNISKOWY KOD REFERENCYJNY ICAO]

ANTONI SWIATECKI (Warszawa, Politechnika, Warsaw, Poland) Technika Lotnicza i Astronautyczna (ISSN 0040-1145), vol. 44, July 1989, p. 18-20. In Polish. refs

A new proposal is made concerning the classification of airports which corresponds to the present-day ICAO and FAA norms. Particular reference is made to Annex 14 to the Convention on International Civil Aviation, eighth edition, and to Advisory Circular No. 150/5325-B Aircraft Data, FAA (1975). B.J.

A90-22242\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

## LIQUID WATER CONTENT AND DROPLET SIZE CALIBRATION OF THE NASA LEWIS ICING RESEARCH TUNNEL

ROBERT F. IDE (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 28 p. Previously announced in STAR as N90-13797. (AIAA PAPER 90-0669) Copyright

The icing research tunnel at the NASA Lewis Research Center underwent a major rehabilitation in 1986 to 1987, necessitating recalibration of the icing cloud. The methods used in the recalibration, including the procedure used to establish a uniform icing cloud and the use of a standard icing blade technique for

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measurement of liquid water content are described. PMS Forward Scattering Spectrometer and Optical Array probes were used for measurement of droplet size. Examples of droplet size distributions are shown for several median volumetric diameters. Finally, the liquid water content/droplet size operating envelopes of the icing tunnel are shown for a range of airspeeds and are compared to the FAA icing certification criteria.

Author

**A90-22762**

**DYNAMIC PROPERTIES OF A SYSTEM FOR THE ROLL CONTROL OF A MODEL ELECTROMAGNETICALLY SUSPENDED IN A WIND TUNNEL [DINAMICHESKIE SVOISTVA SISTEMY UPRAVLENIYA KRENOM MODELI, ELEKTROMAGNITNO PODVESHENNOI V AERODINAMICHESKOI TRUBE]**

V. P. BULEKOV and V. S. VOLKOV (Moskovskii Aviatzionnyi Institut, Moscow, USSR) Priborostroenie (ISSN 0021-3454), vol. 32, Dec. 1989, p. 21-24. In Russian.

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The paper describes an investigation of the dynamic properties of a system for the roll control of a magnetically suspended aircraft model in a wind tunnel. The facility employs eight electromagnets arranged in pairs at an angle of 45 deg to the coordinate axes. An optoelectronic string sensor is used for position determinations.

B.J.

**A90-23364**

**MEASUREMENT OF PROPELLERS IN THE ARTI 3-METER WIND TUNNEL [MERENI VRTULI V AERODYNAMICKEM TUNELU VZLU 3 M]**

SVATOMIR SLAVIK Zpravodaj VZLU (ISSN 0044-5355), no. 5, 1989, p. 303-308. In Czech. refs

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The measurement of propeller characteristics in the ARTI wind tunnel of 3m test section diameter is considered. The autonomous rope strain-gage two-component balance for the 150 kW dynamometer is described. The results are compared with those measured previously with a gravitational tunnel balance. The possibility of utilizing the described balance for a 500 kW dynamometer is discussed.

Author

**A90-23697\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**MAGNETIC SUSPENSION - TODAY'S MARVEL, TOMORROW'S TOOL**

PIERCE L. LAWING (NASA, Langley Research Center, Hampton, VA) University of Oregon, Conference on Low Temperature Physics, 7th, Eugene, OR, Oct. 23-25, 1989, Paper. 13 p. refs

NASA's Langley facility has through constant advocacy of magnetic suspension systems (MSSs) for wind-tunnel model positioning obtained a technology-development status for the requisite large magnets, computers, automatic control techniques, and apparatus configurations, to contemplate the construction of MSSs for large wind tunnels. Attention is presently given to the prospects for MSSs in wind tunnels employing superfluid helium atmospheres to obtain very high Reynolds numbers, where the MSS can yield substantial enhancements of wind tunnel productivity.

O.C.

**N90-15115#** Dundee Univ. (Scotland). Dept. of Civil Engineering.

**DESIGN TEMPERATURES FOR FLEXIBLE AIRFIELD PAVEMENT DESIGN Final Report**

A. F. STOCK Jul. 1989 62 p

(Contract DAJA45-87-M-0484)

(AD-A214141; R/D-5852-EN-01) Avail: NTIS HC A04/MF A01 CSDL 13/3

The mechanistic approach to flexible pavement design recognizes 2 forms of traffic induced structural damage, one being fatigue failure by cracking in the asphalt layer, the other being permanent deformation. The criterion used for ensuring that the pavement does not fail prematurely due to fatigue in the asphalt is based upon tensile strain. It has been shown that the tensile

strain due to aircraft loading has a maximum value at the bottom of the asphalt layer, and it is at this depth that the strain is calculated. The position of the maximum strain relative to the aircraft wheels is dependent upon the aircraft gear configuration, the pavement thickness and stiffness, but is readily determined. Extensive laboratory fatigue tests, combined with full scale trials have permitted the development of a fatigue criterion based on a limiting strain value, so that pavements can be designed to give satisfactory performance.

GRA

**N90-15941\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**THE NASA LANGLEY 0.3-METER TRANSONIC CRYOGENIC TUNNEL**

EDWARD J. RAY In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 21 p Nov. 1989

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The Langley 0.3-Meter Transonic Cryogenic Tunnel (0.3-m TCT) was placed in operation at NASA's Langley Research Center in 1973. This facility was the world's first cryogenic pressure tunnel. The 0.3-m TCT can operate from ambient to cryogenic temperatures at absolute pressures ranging from about 1 to 6 atmospheres. Three major test section concepts were developed and refined in this unique facility. The 0.3-m TCT was a leader in the evolution of cryogenic pressure wind tunnel test techniques, instrumentation, control strategy and model technology. An overview is presented of the evolution and 15 years of experience with the 0.3-m TCT. The historical background concentrates on the technical challenges and proof-of-concept validations during the establishment of the first cryogenic pressure wind tunnel. The various test section concepts are described. Highlights of operational experience and test results determined from these first time exploratory tests are presented. Operating costs and effective test techniques for the 0.3-m TCT are discussed. Finally, current and future plans for the facility are presented.

Author

**N90-15942\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

**THE US NATIONAL TRANSONIC FACILITY, NTF**

WALTER E. BRUCE, JR. and BLAIR B. GLOSS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 27 p Nov. 1989

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The construction of the National Transonic Facility was completed in September 1982 and the start-up and checkout of tunnel systems were performed over the next two years. In August 1984, the Operational Readiness Review (ORR) was conducted and the facility was declared operational for final checkout of cryogenic instrumentation and control systems, and for the aerodynamic calibration and testing to commence. Also, the model access system for the cryogenic mode of operation would be placed into operation along with tunnel testing. Since the ORR, a host of operating problems resulting from the cryogenic environment were identified and solved. These range from making mechanical and electrical systems functional to eliminating temperature induced model vibration to coping with the outgassing of moisture from the thermal insulation. Additionally, a series of aerodynamic tests have demonstrated data quality and provided research data on several configurations. Some of the more significant efforts are reviewed since the ORR and the NTF status concerning hardware, instrumentation and process controls systems, operating constraints imposed by the cryogenic environment, and data quality are summarized.

Author

**N90-15945#** ETW G.m.b.H., Cologne (Germany, F.R.).

**THE EUROPEAN TRANSONIC WINDTUNNEL (ETW)**

XAVIER BOUIS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 16 p Nov. 1989



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The construction phase of the European Transonic Wind Tunnel started recently at Cologne, West Germany. Ambitious goals in aerodynamic quality and cost-effectiveness are reflected in the design philosophy. The main features of the future facility are presented. Author

**N90-15947#** Deutsche Forschungsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stromungsmechanik.

**THE CRYOGENIC LUDWIG TUBE TUNNEL AT GOETTINGEN**  
G. HEFER /In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 7 p Nov. 1989

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At the Research Center Goettingen of the DLR a cryogenic Ludwig tube wind tunnel for transonic operation was constructed. The tunnel, having an effective run time of 1 second, a test section of 0.4 x 0.35 m squared, and a maximum stagnation pressure of 10 bars, is to be operated with nitrogen at temperatures between ambient and 120 K, achieving a Reynolds number of  $70 \times 10^6$  (exp 6) based on a model chord of 0.15 m. This lecture gives a brief review of the Ludwig tube concept, the main design features of the tunnel, and the status of the project and presents the first results of the calibration. Author

**N90-15948\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### OTHER CRYOGENIC WIND TUNNEL PROJECTS

ROBERT A. KILGORE /In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 12 p Nov. 1989

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The first cryogenic tunnel was built in 1972. Since then, many cryogenic wind-tunnel projects were started at aeronautical research centers around the world. Some of the more significant of these projects are described which are not covered by other lecturers at this Special Course. Described are cryogenic wind-tunnel projects in five countries: China (Chinese Aeronautical Research and Development Center); England (College of Aeronautics at Cranfield, and Royal Aerospace Establishment-Bedford); Japan (National Aerospace Laboratory, University of Tsukuba, and National Defense Academy); United States (Douglas Aircraft Co., University of Illinois at Urbana-Champaign and NASA Langley); and U.S.S.R. (Central Aero-Hydrodynamics Institute (TsAGI), Institute of Theoretical and Applied Mechanics (ITAM), and Physical-Mechanical Institute at Kharkov (PMI-K). Author

**N90-15952\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### TEST TECHNIQUES FOR CRYOGENIC WIND TUNNELS

PIERCE L. LAWING /In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 12 p Nov. 1989

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Some of the testing techniques developed for transonic cryogenic tunnels are presented. Techniques are emphasized which required special development or were unique because of the opportunities offered by cryogenic operation. Measuring the static aerodynamic coefficients normally used to determine component efficiency is discussed. The first topic is testing of two dimensional airfoils at transonic Mach numbers and flight values of Reynolds number. Three dimensional tests of complete configurations and sidewall mounted wings are also described. Since flight Reynolds numbers are of interest, free transition must be allowed. A discussion is given of wind tunnel and model construction effects on transition location. Time dependent phenomena, fluid me-

chanics, and measurement techniques are examined. The time dependent, or unsteady, aerodynamic test techniques described include testing for flutter, buffet, and oscillating airfoil characteristics. In describing non-intrusive laser techniques, discussions are given regarding optical access, seeding, forward scatter lasers, two-spot lasers, and laser holography. Methods of detecting transition and separation are reported and a new type of skin friction balance is described. Author

**N90-15956\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### MODELS FOR CRYOGENIC WIND TUNNELS

PIERCE L. LAWING /In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 14 p Nov. 1989

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Model requirements, types of model construction methods, and research in new ways to build models are discussed. The 0.3-m Transonic Cryogenic Tunnel was in operation for 16 years and many 2-D airfoil pressure models were tested. In addition there were airfoil models dedicated to transition detection techniques and other specialized research. There were also a number of small 3-D models tested. A chronological development in model building technique is described which led to the construction of many successful models. The difficulties of construction are illustrated by discussing several unsuccessful model fabrication attempts. The National Transonic Facility, a newer and much larger tunnel, was used to test a variety of models including a submarine, transport and fighter configurations, and the Shuttle Orbiter. A new method of building pressure models was developed and is described. The method is centered on the concept of bonding together plates with pressure channels etched into the bond planes, which provides high density pressure instrumentation with minimum demand on parent model material. With care in the choice of materials and technique, vacuum brazing can be used to produce strong bonds without blocking pressure channels and with no bonding voids between channels. Using multiple plates, a 5 percent wing with 96 orifices was constructed and tested in a transonic cryogenic wind tunnel. Samples of test data are presented and future applications of the technology are suggested. Author

**N90-15957\*#** National Aeronautics and Space Administration, Langley Research Center, Hampton, VA.

#### AUTOMATIC CONTROL OF CRYOGENIC WIND TUNNELS

S. BALAKRISHNA /In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 15 p Nov. 1989

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Inadequate Reynolds number similarity in testing of scaled models affects the quality of aerodynamic data from wind tunnels. This is due to scale effects of boundary-layer shock wave interaction which is likely to be severe at transonic speeds. The idea of operation of wind tunnels using test gas cooled to cryogenic temperatures has yielded a quantum jump in the ability to realize full scale Reynolds number flow similarity in small transonic tunnels. In such tunnels, the basic flow control problem consists of obtaining and maintaining the desired test section flow parameters. Mach number, Reynolds number, and dynamic pressure are the three flow parameters that are usually required to be kept constant during the period of model aerodynamic data acquisition. The series of activity involved in modeling, control law development, mechanization of the control laws on a microcomputer, and the performance of a globally stable automatic control system for the 0.3-m Transonic Cryogenic Tunnel (TCT) are discussed. A lumped multi-variable nonlinear dynamic model of the cryogenic tunnel, generation of a set of linear control laws for small perturbation, and nonlinear control strategy for large set point changes including tunnel trajectory control are described. The details of mechanization of the control laws on a 16 bit microcomputer system, the software features, operator interface, the display and safety are discussed.

## 09 RESEARCH AND SUPPORT FACILITIES (AIR)

The controller is shown to provide globally stable and reliable temperature control to + or - 0.2 K, pressure to + or - 0.07 psi and Mach number to + or - 0.002 of the set point value. This performance is obtained both during large set point commands as for a tunnel cooldown, and during aerodynamic data acquisition with intrusive activity like geometrical changes in the test section such as angle of attack changes, drag rake movements, wall adaptation and sidewall boundary-layer removal. Feasibility of the use of an automatic Reynolds number control mode with fixed Mach number control is demonstrated. Author

**N90-15958\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **EXPERIENCE WITH STRAIN-GAGE BALANCES FOR CRYOGENIC WIND TUNNELS**

M. SUSAN WILLIAMS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 14 p Nov. 1989  
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The U.S. National Transonic Facility (NTF) is a cryogenic wind tunnel build to meet the United States' needs for high Reynolds number testing. The facility was declared operational in August 1984, and since that time numerous models were tested in the NTF using unheated strain-gage balances to measure aerodynamic forces. The difficulty in accurately measuring forces and moments of models in conventional wind tunnels becomes more challenging at cryogenic conditions. The Force and Strain Instrumentation Section of the Instrument Research Division at NASA Langley Research Center designed and fabricated the balances to measure forces at cryogenic temperatures without thermally controlling the balance temperature. Presented are balance results from a recent cryogenic test program in the NTF. The data indicated the accuracy with which aerodynamic forces are determined using current instrumentation and test methods as well as identified areas for future research. Author

**N90-15959\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **CRYOGENIC BALANCES FOR THE US NTF Status Report**

ALICE T. FERRIS In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 10 p Nov. 1989  
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Force balances were used to obtain aerodynamic data in the National Transonic Facility (NTF) wind tunnel since it became operational in 1983. These balances were designed, fabricated, gaged, and calibrated to Langley Research Center's specifications to operate over the temperature range of -320 F to +140 F without thermal control. Some of the materials and procedures developed to obtain a balance that would perform in this environment are reviewed. The degree of success in using these balances thus far is reported. Some of the problem areas that need additional work are specified and some of the progress addressing these problems is described. Author

**N90-15960\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

### **SAFETY AND CRYOGENIC WIND TUNNELS**

EDWARD J. RAY In AGARD, Special Course on Advances in Cryogenic Wind Tunnel Technology 18 p Nov. 1989  
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The Langley 0.3-Meter Transonic Cryogenic Tunnel (0.3-m TCT) was placed in operation at NASA's Langley Research Center in 1973 as the world's first cryogenic pressure tunnel. The 0.3-m TCT can operate from ambient to cryogenic temperatures over an absolute pressure range from about 1 to 6 atmospheres. Three major test section concepts were developed and refined in this unique facility. The 0.3-m TCT is a leader in the development of various cryogenic pressure wind tunnel experimental techniques,

instrumentation, control, model technology and safety standards. The safety experience gained is examined. During this period of advanced research, new operating techniques, training policies, and procedures had to be established. The paper deals with the Do's and Don'ts of cryogenic wind tunnel testing. Hazards and safety requirements which are unique to cryogenic testing are discussed. Highlights of experience and lessons learned with the 0.3-m TCT are reviewed. Author

**N90-15963#** European Space Agency, Paris (France).

### **PRESSURE MEASUREMENT TECHNIQUE IN THE WIND TUNNEL DIVISION OF DFVLR Status Report, 1988**

RUEDIGER SIEBERT Oct. 1989 52 p Original language document was announced as N89-25243

(ESA-TT-1145; DFVLR-MITT-88-11; ETN-90-96190) Avail: NTIS HC A04/MF A01; original German version available from DFVLR, VB-PL-DO, Postfach 90 60 58, 5000 Cologne, Fed. Republic of Germany, 19.50 DM

Information for users of the DFVLR wind tunnels in Brunswick, Goettingen and Cologne (Germany, F.R.) is presented. The general concept, technical details and status of the pressure measuring technique are described. The data on all the available pressure sensors and pressure measuring systems are provided. A modern and powerful pressure measurement technique available for wind tunnel users is described. Compatible measuring systems permit use on various wind tunnels. An adequate measure of flexibility is retained and it is possible to react quickly even to varying requirements. ESA

## 10

## ASTRONAUTICS

Includes astronautics (general); astrodynamics; ground support systems and facilities (space); launch vehicles and space vehicles; space transportation; spacecraft communications, command and tracking; spacecraft design, testing and performance; spacecraft instrumentation; and spacecraft propulsion and power.

**A90-21546**

### **THE NATIONAL AERO-SPACE PLANE, THE GUIDANCE AND CONTROL ENGINEER'S DREAM OR NIGHTMARE?**

FELIX SANCHEZ (USAF, Joint Program Office, Wright-Patterson AFB, OH) IN: Guidance and control 1989: Proceedings of the Annual Rocky Mountain Guidance and Control Conference, Keystone, CO, Feb. 4-8, 1989. San Diego, CA, Univelt, Inc., 1989, p. 339-352.

(AAS PAPER 89-040) Copyright

Major technical challenges associated with the National Aerospace Plane (NASP) Program are discussed, including the ones viewed from a controls perspective. Design and engineering challenges encountered in the propulsion system, the structural material selection, and the computational fluid dynamic mechanisms to predict Mach 8+ regimes, are briefly discussed. Emphasis is put on those significant challenges in the guidance and control fields relating to vehicle management systems, integrated propulsion/flight control, optimal vehicle trajectory control, and challenges in the associated fields on instrumentation and information systems. An insight into the complexity of the problem is provided, and the importance of guidance and control in future NASP achievements is highlighted. C.E.

**A90-21716#**

### **POTENTIAL APPLICATIONS OF SATELLITE NAVIGATION**

#### **[EINSATZMOEGLICHKEITEN VON SATELLITENNAVIGATION]**

G. SCHAEENZER (Braunschweig, Technische Universitaet, Brunswick, Federal Republic of Germany) Ortung und Navigation (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 346-357. In German.

The applicability of Navstar GPS to civil air navigation is discussed. The accuracy of current air-navigation systems is

## CHEMISTRY AND MATERIALS

Includes chemistry and materials (general); composite materials; inorganic and physical chemistry; metallic materials; nonmetallic materials; and propellants and fuels.

reviewed; the basic principle and accuracy of GPS navigation are characterized; the relatively low cost of GPS receiving equipment is pointed out; and particular attention is given to hybrid systems combining GPS with inertial navigation. It is predicted that CAT III landings will be possible using such hybrid systems when the GPS satellites are fully deployed, even without access to the military GPS code. Techniques for GPS-based precision landings, reduced-noise landings, landings on parallel runways, control of taxiing maneuvers, and aircraft-based geodetic measurements are briefly described and illustrated with diagrams. T.K.

A90-21717#

**STATUS AND POTENTIAL OF GPS-RECEIVER DEVELOPMENT  
[STAND UND MOEGLICHKEITEN DER  
GPS-EMPFAENGERENTWICKLUNG]**

DIETRICH RAHLFS (Standard Elektrik Lorenz AG, Stuttgart, Federal Republic of Germany) *Ortung und Navigation* (ISSN 0474-7550), vol. 30, no. 3, 1989, p. 358-365. In German.

The current development status of receivers for Navstar GPS is surveyed, with a focus on equipment for civil aircraft navigation. The basic characteristics of five-channel P-code and six-channel C/A-code receivers are reviewed and illustrated with block diagrams; recent advances in GPS antennas and signal-processing techniques are outlined; and possible approaches to a low-cost accurate aircraft system are considered. Particular attention is given to (1) a high-availability modular GPS/MLS/DME-P navigation system and (2) an integrated system combining GPS, Glonass, MLS-DME-P, and inertial navigation (e.g., a strapdown fiber-optic gyro). T.K.

A90-23202

**AIRBORNE ARRAY ANTENNAS FOR SATELLITE  
COMMUNICATION**

MASAYUKI YASUNAGA, FUMIO WATANABE, and TAKAYASU SHIOKAWA (Kokusai Denshin Denwa Co., Ltd., Research and Development Laboratories, Tokyo, Japan) *Space Communications* (ISSN 0167-9368), vol. 7, Dec. 1989, p. 11-17. refs

Copyright

The configurations and electrical characteristics of two low-profile, lightweight, small, electrically scanning airborne phased-array antenna are presented. One of the antennas is a microstrip array antenna and the other is a cross-slot array antenna. The active feed system of a phased-array antenna and multipath fading due to sea surface reflection in aeronautical satellite communications are examined. R.B.

A90-23428

**ELECTRODYNAMIC PROPERTIES OF ENGINE EXHAUST JETS  
[ELEKTRODINAMICHESKIE SVOISTVA VYKHLOPNOI STRUI  
DVIGATELEI]**

G. P. POTAPOV *Aviatsionnaya Tekhnika* (ISSN 0579-2975), no. 4, 1989, p. 93-96. In Russian. refs

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The objective of the study was to investigate the possibility of using the electrodynamic properties of the double electric boundary layer at the exit section of a jet engine nozzle for engine diagnostics. It is demonstrated that the engine operating regimes can be determined by monitoring the electromagnetic emission of the engine-exhaust jet system. The approach proposed here makes it possible to use simple active and passive methods for controlling the principal operating parameters of flight vehicle powerplants. V.L.

A90-20064

**EXPERIMENTAL DETERMINATION OF THE SHORT CRACK  
EFFECT FOR METALS**

C. J. MAZUR and J. L. RUDD (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH) IN: *International Congress on Experimental Mechanics*, 6th, Portland, OR, June 6-10, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 850-857. Research supported by USAF. refs

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Unconservative life predictions for aircraft structure may occur if the 'short crack effect' exists. The objective of this effort is to verify the existence of such an effect. This verification is accomplished through a comprehensive test program involving short crack tests on 2024-T351 aluminum and 2090-T8E41 aluminum lithium. This paper presents the experimental technique used to monitor the growth of the short cracks and the results of the test program. Author

A90-20259#

**MATERIAL OF THE '90S?**

ALAN S. BROWN *Aerospace America* (ISSN 0740-722X), vol. 28, Jan. 1990, p. 28-31, 33.

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The National Materials Advisory Board 1987 report titled 'The Place for Thermoplastic Composites in Structural Composites' identified four areas of preeminent importance for intensive industry attention: (1) the development of inexpensive, large-scale manufacturing methods; (2) the formulation of innovative joining processes; (3) the identification of characterization methods and compilation of data bases for comparison of performance levels; and (4) the creation of novel polymer-synthesis methods which begin with low melting-point resins to create high molecular-weight polymers. A dramatic recent response to the last requirement is the formulation of a low-temperature method which turns a low-viscosity thermoplastic resin into a high molecular weight matrix for composite applications. O.C.

A90-20263

**MORE COMPOSITES IN COMMERCIAL TRANSPORTS?**

*Aerospace Engineering* (ISSN 0736-2536), vol. 9, Dec. 1989, p. 19-22.

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A substantial number of problems must be solved before polymer-matrix composites can be extensively used in heavily loaded areas of commercial transport primary structures. Development priorities exist for the problems of poor damage tolerance and delamination resistance, high material costs, excessive labor intensiveness in manufacture, and an insufficient data base for accurate risk evaluation, structural-integrity prediction, and certification requirements definition. Research activities underway are concerned with the development of processable high-temperature thermoplastics, toughened high-temperature thermosets, semicrystalline polyimides, and resin blends. O.C.

A90-20607

**GEAR STEELS FOR FUTURE HELICOPTER TRANSMISSIONS**

D. P. DAVIES and B. C. GITTO (Westland Helicopters, Ltd., Yeovil, England) (Seminar on Design of Aerospace Transmissions, Taunton, England, Mar. 29, 1988) *Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering* (ISSN 0954-4100), vol. 203, no. G2, 1989, p. 113-121. Research supported by the Ministry of Defence Procurement Executive.

refs

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Future helicopter transmissions are presently forecast to incorporate design changes in the interest of weight reduction, reliability improvement, and safety enhancement, which place more strenuous demands on gear steels. Due to their ability to reach operating temperatures of more than 550 C without deterioration, the hot hardness capability of nitriding steels is noted to be substantially greater than that of conventional carburized steels; they offer, unfortunately, lower core strengths and shallower case depths. Attention is given to two methods recently developed for the increase of case depths. O.C.

**A90-20775**

**SUPERALLOY 718: METALLURGY AND APPLICATIONS; PROCEEDINGS OF THE INTERNATIONAL SYMPOSIUM, PITTSBURGH, PA, JUNE 12-14, 1989**

EDWARD A. LORIA, ED. (Niobium Products Co., Pittsburgh, PA) Symposium sponsored by the Minerals, Metals and Materials Society, ASM International, and National Association of Corrosion Engineers. Warrendale, PA, Minerals, Metals and Materials Society, 1989, 710 p. No individual items are abstracted in this volume. Copyright

Recent advances in the metallurgy and applications of superalloy 718 (S718) are examined in reviews and reports. Topics addressed include melting technology for S718, solidification control in VAR and ESR S718 ingots, application of a modified phase diagram to the production of cast S718 components, microstructural characterization of cast S718, the hot deformation behavior of as-cast S718 ingots, and the effects of starting condition on the aging response of as-forged S718. Consideration is given to the long-term stability of a wrought S718 disk; P/M S718 tubing produced by cold radial forging, laser cladding of Astroloy on S718, the mechanical properties and microstructure of fine-grain centrifugally cast S718, the phase stability and aging response of TiC-reinforced S718, and the analysis and elimination of time-dependent notch sensitivity in S718. T.K.

**A90-21318**

**STRENGTH OF THE GUIDE VANE COMPONENTS OF GAS TURBINES [K VOPROSU O PROCHNOSTI DETALEI NAPRAVLIAUSHCHIKH APPARATOV GAZOVYKH TURBIN]**

A. R. BELIAKOV, L. B. GETSOV, A. E. GINZBURG, K. M. KONONOV, and V. V. BARSKOV Problemy Prochnosti (ISSN 0556-171X), Nov. 1989, p. 119-124. In Russian. refs Copyright

The principal types of damage observed in the components of guide vanes of gas turbines, such as cracking, irreversible deformation, and blade edge bends, are analyzed. Methods for calculating the safety factor of guide vane components under conditions of thermal cycling are then presented which are based on the adaptability theory. The discussion is illustrated by experimental results obtained for guide vane components made of 20Kh23N18 steel and El868 nickel alloy. V.L.

**A90-21473**

**OILS FOR FLIGHT TURBINE ENGINES - RESEARCH AND DEVELOPMENT IN THE 90S [OELE FUER FLUGTURBINENANTRIEBE - FORSCHUNG UND ENTWICKLUNG IN DEN 90ER JAHREN]**

EILHARD JANTZEN (DLR, Institut fuer technische Physik, Stuttgart, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), Nov. 1989, p. 71-73. In German. refs Copyright

The high temperatures of flight turbine engines in the 1990s will require new oils, as the present ones based on esters have reached the temperature limits of their applicability. This paper discusses the characteristics of oils that need to be developed in the 1990s, including oils for propfan engines, for hypersonic engines, and for future high-performance engines. The physical properties and behaviors of the oils required for these applications are pointed out. C.D.

**A90-21774**

**HYDROGEN PROPULSION AND THE NEXT CENTURY - A CHALLENGE THAT RAISES QUESTIONS AND PROBLEMS [MIT WASSERSTOFF-ANTRIEB INS NAECHSTE JAHRHUNDERT - EINE HERAUSFORDERUNG, DIE FRAGEN UND PROBLEME AUFWIRFT]**

CARL-JOCHEN WINTER (DLR, Stuttgart, Federal Republic of Germany) Luft- und Raumfahrt (ISSN 0173-6264), vol. 10, 4th Quarter, 1989, p. 26-28, 30, 32. In German. Copyright

The prospects for the use of hydrogen propulsion in the aircraft of the 21st century are addressed. The economic benefits of such propulsion are pointed out, and the risks posed by the use of the explosive gas and the safety measures needed to cope with them are examined. Work being done on a hydrogen-propelled Airbus is discussed. C.D.

**A90-22183#**

**SUPERSONIC COMBUSTION OF HYDROGEN JETS BEHIND A BACKWARD-FACING STEP**

S. M. CORREA, R. E. WARREN, F. F. HALLER, and W. O. KAISER (GE Corporate Research and Development Center, Schenectady, NY) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 7 p. refs (AIAA PAPER 90-0204) Copyright

The combustion of an array of hydrogen jets behind a backward-facing step in supersonic flow is studied. A study of the equivalent nonreacting flow with air jets is extended to the combustion case. Experiments are performed in a variable-geometry Mach 1.8-4.0 wind-tunnel with a 6 x 6-in test-section operated in a heat-sink mode. H<sub>2</sub> enters perpendicularly through a spanwise array of jets behind the 0.5-in step. Increasing the overall equivalence ratio increases the pressure jump, but reduces the wall temperatures, implying cooling by the stratified H<sub>2</sub>-air mixture. Three-dimensional effects are confined to the near-field of the jets and the step. The flow rapidly two-dimensionalizes itself into a shear layer between the supersonic air stream and the fuel-rich stream behind the step. Author

**A90-22192#**

**A ONE-DIMENSIONAL MODEL OF RAMJET COMBUSTION INSTABILITY**

R. BHATIA and W. A. SIRIGNANO (California, University, Irvine) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 15 p. refs (Contract N00014-85-K-0658) (AIAA PAPER 90-0271) Copyright

A one-dimensional numerical analysis is performed to investigate the effects of various design parameters on the stability of the combustion process in liquid-fueled ramjets. The parameters considered include spray characteristics, mixture ratio profiles, and combustor geometry. Special emphasis is given to the computation of the unsteady solution for the gas and liquid phases, evaluation of the effects of inlet gas velocity perturbations, and the coupling between gas and liquid phases under perturbed conditions. C.D.

**A90-22595#**

**HIGH-PERFORMANCE COMPOSITE MATERIALS IN AIR AND SPACE TRAVEL - STATE OF THE ART AND FUTURE PERSPECTIVES [HOCHLEISTUNGSVERBUNDWERKSTOFFE IN DER LUFT- UND RAUMFAHRT - STAND UND ZUKUNFTSPERSPEKTIVEN]**

J. BRANDT (MBB GmbH, Munich, Federal Republic of Germany) Fachtagung ueber Faserverbundwerkstoffe auf dem Weg in die Zukunft, Wuerzburg, Federal Republic of Germany, Oct. 18, 19, 1989, Paper. 24 p. In German. refs (MBB-Z-0279/89)

The state of the art in fiber composite materials for air and space vehicles has seen significant advances in the strength of fibers, especially carbon fibers, even as demands placed on matrix systems have increased correspondingly. Limiting factors in future use of these materials include insufficient toughness, the effects of moisture, and the relatively low temperature range of application

of epoxy resin. High materials and labor costs are also an important factor. The need to increase damage tolerance in fiber composite materials is also addressed. C.D.

**A90-23177**

# **AEROSPACE MATERIALS RESEARCH OPPORTUNITIES**

MICHAEL SALKIND (USAF, Office of Scientific Research, Washington, DC) Advanced Materials (ISSN 0044-8249), no. 5, 1989, p. 157-164. refs

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The comprehensive evaluation of trends and prospects in the field of aerospace structural materials presented notes that an evolutionary point has been reached at which the processing of natural substances will be increasingly supplanted by the direct synthesis of microstructures to address design problems. The mathematical modeling of microstructure-property relationships, as well as novel chemical and biotechnical synthesis techniques, are accordingly identified as critical technologies for future development. Prospective materials developers will require a broader understanding of the total structural service life cycle, in order to simultaneously consider the impact of utilization, maintenance, and training requirements. O.C.

**N90-15185#** Advisory Group for Aerospace Research and Development, Neuilly-Sur-Seine (France). Structures and Materials Panel.

## **NEW LIGHT ALLOYS**

Aug. 1989 364 p In ENGLISH and FRENCH Meeting held in Mierlo, Netherlands, 3-5 Oct. 1988

(AGARD-CP-444; ISBN-92-835-0519-0) Copyright Avail: NTIS HC A16/MF A02; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

The status of current developments in aluminum-lithium alloys, the characterization of commercially available products, and their likely applications in aircraft structures were reviewed. Also considered were developments in other lightweight metallic materials such as magnesium alloys, aluminum powder metallurgy alloys and aluminum metal matrix composites.

**N90-15187#** Virginia Univ., Charlottesville. School of Engineering and Applied Science.

## **THE MICROSTRUCTURE AND PROPERTIES OF ALUMINUM-LITHIUM ALLOYS**

EDGAR A. STARKE, JR. and WILLIAM E. QUIST (Boeing Commercial Airplane Co., Seattle, WA.) In AGARD, New Light Alloys 23 p Aug. 1989

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The advantage to be gained by weight reduction of aerospace structures have encouraged the aluminum industry to develop a family of aluminum alloys which contain lithium as one of the alloying elements. When alloyed with aluminum, lithium can reduce the density by approximately three percent and increase the elastic modulus by six percent for every weight percent added. A new series of aluminum alloys, typified by 2090, 2091, 8090, and 8091, were developed and are currently being produced in commercial quantities. These alloys have densities between 7 and 10 percent lower than the conventional alloy 7075 with correspondingly higher stiffness. Although a combined set of specific properties of the Al-Li-X alloys often exceeds those of the conventional aluminum materials used in aerospace, these properties seem to be much more sensitive to processing parameters. The strong processing-property relationship is associated with sharp crystallographic textures that are developed during primary processing and very complex precipitate microstructures whose distributions are sensitive to quench rates and degree of deformation prior to aging. The processing-microstructure property relationships of the new Al-Li-X alloys are described and the focus is on strength, ductility, fracture toughness, fatigue and stress corrosion properties. Author

**N90-15191#** Laboratoire Central Aerospatiale, Suresnes Cedex (France). Section Metallurgie.

## **PROPERTIES OF AL-LI ALLOYS [PROPRIETES DES ALLIAGES AL-LI]**

Y. BARBAUX In AGARD, New Light Alloys 18 p Aug. 1989 In FRENCH Sponsored by Service Technique des Programmes Aeronautiques, France

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Investigations of commercial aluminum lithium alloys conducted by Aerospatiale in the last five years are summarized. The characterization and application of thin metal sheets of 2091 CPH T8X and 8090C T81, medium-thickness sheets of 2091 T8x51, and structural sections of 8090 and 2091 T8511 are discussed. The eventual application of some of these materials in the A-340 Airbus is also discussed. Transl. by M.G.

**N90-15192#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport Aircraft Group.

## **INVESTIGATION ON SHEET MATERIAL OF 8090 AND 2091 ALUMINUM-LITHIUM ALLOY**

W. ZINK, J. WEILKE, L. SCHWARMANN, and K. H. RENDIGS In AGARD, New Light Alloys 15 p Aug. 1989

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The new aluminum-lithium alloys offer an attractive alternative of reducing structural weight for civil aircraft components. For fuselage application the damage tolerant version of aluminum-lithium as substitution of 2024 T3 material is of greatest interest. Due to the responsibility of MBB/UT for fuselage structures within the Airbus production sharing investigations on damage tolerant 8090 and 2091 sheet material was carried out a few years ago. The Al-Li alloys 2091 and 8090, developed by Pechiney, Alcoa, and Alcan for 2024 T3 substitution will be presented in view of mechanical properties and damage tolerant behavior with special emphasis placed on the comparison with conventional alloys. Fracture toughness data from R-Curves performed on CCT-specimens as well as crack propagation behavior and fatigue results will be discussed. Finally, a summary will be given on the different corrosion behaviors. Author

**N90-15193#** Naval Air Development Center, Warminster, PA.

## **ALUMINUM LITHIUM ALLOYS FOR NAVY AIRCRAFT**

E. W. LEE and J. WALDMAN In AGARD, New Light Alloys 10 p Aug. 1989

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Ingot metallurgy alloys of aluminum with lithium additions offer large gains in structural efficiency due to reduced density together with increased strength and elastic modulus. Several alloys are now commercially available. The Navy was sponsoring research and development activities in these alloys since the mid-seventies. Current efforts include ongoing multi-laboratory evaluations of aluminum alloys to replace 7075-T6 and 7075-T73. The Navy is also conducting research and development on thermal mechanical processing and superplastic forming on these alloys. Additional testing is being conducted to determine their corrosion resistance in an aircraft carrier environment. Author

**N90-15196#** Fokker B.V., Schiphol-Oost (Netherlands). Material and Fabrication Technology.

## **FABRICATION OF TEST-ARTICLES FROM AL-LI 2091 FOR FOKKER 100**

G. J. H. VAESSEN, C. VANTILBORGH, and H. W. VANROOIJEN In AGARD, New Light Alloys 12 p Aug. 1989

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The technical requirements for introduction of aluminum-lithium alloys in secondary structures of aircraft are formulated. The

general corrosion behavior, stress-corrosion properties, and mechanical properties of the alloy 2091-T3 from Cegedur-Pechiney meet these requirements. The successful fabrication of access doors in the underwing fairing of the Fokker 100 is described. The same manufacturing techniques as for 2024 can be used for 2091, i.e., machining, blanking, bending, chemical milling, surface pretreatments, adhesive bonding, solution heat treatment and drop-hammer forming, stretch forming, painting and riveting. Operational in-service trial on Fokker 100 and F28 operated by major airlines as Swissair and Garuda has started. An estimate of the cost-effectiveness of the access doors out of 2091 is given.

Author

**N90-15197#** Avions Marcel Dassault-Breguet Aviation, Saint-Cloud (France).

## **PUTTING ALLOY 2091 TO WORK [MISE EN OEUVRE DE L'ALLIAGE 2091]**

J. BEVALOT /in AGARD, New Light Alloys 7 p Aug. 1989 In FRENCH

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Assessments leading to the replacement of alloy 2024 T3 with the aluminum-lithium alloy 2091 in aircraft applications are discussed. Formability, metallurgical characteristics, and fatigue properties of alloy 2091 are discussed and compared with those of alloy 2024. Alloy 2091 has very good deformation characteristics allowing the formation of panels in one pass with cold tempering instead of two passes for alloy 2024. The working time with cold tempering is very long with the 2091 alloy -- on the order of three days. In addition, alloy 2091 was found to have very good spot weld properties, good chemical machinability, and the same protection ranges as alloy 2024.

Transl. by M.G.

**N90-15198#** British Aerospace Public Ltd. Co., Bristol (England). Production Development and Methods.

## **FABRICATION CHARACTERISTICS OF 8090 ALLOY**

V. H. MOULD /in AGARD, New Light Alloys 10 p Aug. 1989

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Some of the experience gained so far, by a user, during a production process evaluation of 8090 medium strength Al-Li alloy is collated. The four primary production processes, machining, forming, joining, and construction, in this sense finishing, treatments, painting, plating classed as secondary processes are examined. Sufficient work was completed to give confidence in the ability of this material to respond to these four basic processes, and produce a quality article. No fundamental changes will be required of machine tools, cutting tools, plant, or equipment. Some techniques will change from conventional alloy requirements, particularly with forming, where further work is required, as 8090 does not form well in the cold condition. It is concluded that 8090 medium strength Al-Li alloy is becoming available in sufficient quantity and quality to enable design engineers to specify the material for applications that can exploit the proven weight and strength advantages. The final responsibility resting with the manufacturing engineers is to ensure that Al-Li can be utilized as an economic proposition.

Author

**N90-15200#** Airbus Industrie, Blagnac (France). Advanced Structures and Materials.

## **POINT OF VIEW OF A CIVIL AIRCRAFT MANUFACTURER ON AL-LI ALLOY**

JOHANNES KOSHORST /in AGARD, New Light Alloys 5 p Aug. 1989

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The process of evaluating a new material for use in a civil transport aircraft is rather complex and long. The introduction of Al-Li appears as being a particular difficult item. Initially developed for application in combat aircraft aiming for high strength properties,

a civil transport airplane however requires Al-Li in a damage tolerant version. Equivalence to existing alloys is requested (equal or better) but Al-Li demands a compromise between major properties as strength, damage tolerance and corrosion resistance. Progress in achieving acceptable and harmonized material quality is very slow and time constraints have prevented introduction in a planned way in a number of programs. The question is raised whether a cost effective use of Al-Li can be envisaged over the next years.

Author

## **N90-15201# Westland Helicopters Ltd., Yeovil (England). USES AND PROPERTIES OF AL-LI ON THE NEW EH101 HELICOPTER**

A. F. SMITH /in AGARD, New Light Alloys 19 p Aug. 1989

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The EH101 is a long range, large capacity helicopter developed and built to meet the needs of civil, naval, and utility operations and in which many new aerodynamic, electronic and structural design concepts are successfully combined. In order to effect significant structural weight reductions, extensive use will be made of aluminum-lithium based alloys which are now becoming commercially available. The results of a weight-saving cost analysis favor the use of aluminum-lithium sheet, extruded profiles and forgings on the EH101, while corresponding plate and extruded bar will not be used due to the combined effects of low utilization rate and the inherently higher material cost of aluminum-lithium. Accordingly, greater emphasis is being placed upon the use of die forgings, particularly for the manufacture of components hitherto machined from non-lithium containing aluminum plate. Extensive evaluation programs are currently in progress covering AA 8090 and AA 2091 sheet, together with specific EH101 extruded profiles and forgings also in AA 8090 but with additional studies in alloy AA 8091; comparisons will be made with alloys AA 2014, 2024, 7075 and 7010 where appropriate. Notwithstanding the lower ductilities and anisotropic effects characteristic of aluminum-lithium, the results to date show that direct substitution of current aluminum alloys may be realistically pursued, particularly as superior fatigue properties are indicated in the new materials. The use of aluminum-lithium based alloys on the EH101 are reviewed and the findings of the current studies reported.

Author

**N90-15202#** McDonnell Aircraft Co., Saint Louis, MO. Materials and Process Development Branch.

## **ALUMINUM-LITHIUM: APPLICATION OF PLATE AND SHEET TO FIGHTER AIRCRAFT**

BYRON A. DAVIS /in AGARD, New Light Alloys 11 p Aug. 1989

(Contract MCAIR PROJ. 7-220)

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The potential for weight savings resulting from the low density and high stiffness of aluminum-lithium (Al-Li) alloys led to the consideration of Al-Li alloys for use on both new and existing aircraft. The successful fabrication, and flight testing of several demonstration parts on both the F-15 and F/A-18 increased interest in these alloys. In support of these and other applications of Al-Li plate and sheet, the mechanical properties, conventional formability, and superplastic formability of 2090 and 8090 were evaluated. With a few notable exceptions, such as the anisotropy in sheet, these Al-Li alloys were comparable to conventional aluminum alloys. Chemical processing and corrosion resistance of 2090 and 8090 were also investigated and again were found comparable to conventional aluminum.

Author

**N90-15203#** Royal Aerospace Establishment, Farnborough (England). Materials and Structures Dept.

## **CURRENT STATUS OF THE APPLICATION OF CONVENTIONAL ALUMINIUM-LITHIUM ALLOYS AND THE POTENTIAL FOR FUTURE DEVELOPMENTS**

C. J. PEEL /in AGARD, New Light Alloys 9 p Aug. 1989



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Commercial aluminum-lithium alloys are now entering service use and, while it cannot be claimed that they are yet fully achieving their maximum potential, it is now appropriate to consider the limitations to their further development and the possibilities for the development of other systems and composites based on light alloys, especially suited for aerospace structures. All the commercial aluminum-lithium alloys presently offered were designed to present a reduction in density and an increase in elastic modulus as their main benefits to the designers contemplating their application. The other important metallurgical properties of the alloys, such as strength and fracture toughness were matched to the performance of existing 2000 and 7000 series alloys. The possibilities for further density reductions and increases in mechanical properties, comparing the potential improvements with those offered by non-metallic composites are considered. Three types of structure are considered generically namely damage tolerant structure, typified by a pressurized fuselage skin, structure limited by inadequate material stiffness in either the case of aeroelastic performance or resistance to buckling and structure limited by currently obtainable strength levels at both ambient and elevated temperatures. It transpires from the following brief analysis that future developments may well have to be optimized against the special requirements of the three simple categories outlined and that the simple principle underlying the development of the conventional aluminum-lithium alloys cannot be extended greatly.

Author

**N90-15288#** Pennsylvania State Univ., University Park. Coll. of Earth and Mineral Sciences.

**THERMAL STABILITY OF JET FUEL Quarterly Report No. 4, Jul. - Sep. 1989**

SEMIN ESER, JANICE PERISON, RONALD M. COPENHAVER, and HAROLD H. SCHOBERT 1989 54 p

(Contract DE-AC22-88PC-88827)

(DE90-002760; DOE/PC-88827/T4) Avail: NTIS HC A04/MF A01

The overall objective of this program is to investigate the effect of chemical components on the thermal stability of jet fuel. Six model compounds were heat treated in microautoclave reactors lined with pyrex tubes to investigate the effect of the reactor surface on thermal degradation reactions. These experiments were carried out at 350 to 450 C for 1 to 2 hours in 100 psig cold nitrogen pressure. Reaction products were analyzed by H-1 and C-13 NMR spectroscopy to compare their chemical constitution with those obtained under the same conditions without the glass liners in the reactors. The thermal treatments in air were extended to cover a wider temperature and time range than those indicated in the second quarterly report. The treatment temperature varied between 150 and 450 C for reaction times ranging from 93 hours to 1 hour, respectively. This set of reactions were performed under 100 psig cold air pressure. Reaction products were characterized by H-1 and C-13 NMR spectroscopy and GC-MS analysis. The degradation of 2,6-dimethylphenol is discussed.

DOE

**N90-15909#** Royal Aircraft Establishment, Farnborough (England). Materials and Structures Dept.

**THE EFFECT OF PRIMER AGE ON ADHESION OF POLYSULPHIDE SEALANT**

S. P. WILFORD and J. DAY /In AGARD, Fuel Tank Technology 7 p Nov. 1989

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Sealants used in aircraft integral fuel tanks must adhere well to primed substrate surfaces. The adhesion of polysulphide sealant (PR1422) to primed aluminum alloy surfaces of different primer age was studied with respect to the effect on lap-shear strength of ageing in fuel at 100 C. Freshly primed surfaces, 1 day old, were compared with a range of older primed surfaces. With a standard epoxy chromate primer, primer age has a very marked

effect on lap-shear strength, the value after 10 days in fuel (Avtur) at 100 C being a factor of 2 less for 2 to 20 week old primed specimens as compared to a freshly primed one. In contrast, similar studies using three tolerant epoxy chromate primers indicate that primer age has much less effect on the adhesion of PR1422 sealant to these primers, lap shear strengths after ageing in fuel at 100 C showing much less dependence on primer age. These results would appear to be very relevant to both repair and manufacture of integral fuel tanks.

Author

**N90-15911#** Products Research and Chemical Corp., Glendale, CA.

**FUEL RESISTANT COATINGS FOR METAL AND COMPOSITE FUEL TANKS**

SANTO RANDAZZO /In AGARD, Fuel Tank Technology 20 p Nov. 1989

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Coating systems based on fuel resistant polythioether polyurethane polymers were developed. These systems are formulated to provide a secondary seal and thereby protect the interior of composite fuel tanks. In addition to fuel resistance the systems have excellent physical properties, low specific gravity and prevent fuel leakage even after severe impact damage to the composite tank. Reduction of mechanical damage, prevention of water penetration into the composite, and prevention of leakage through composite imperfections are other desirable properties of these coatings. Data are presented showing the fuel resistance and hydrolytic stability of these new materials. The retention of physical properties is tabulated after prolonged environmental exposure to fuel and water. Impact damage data on coated composites and metal is presented using different energy levels of impact and various thicknesses of coating. The effectiveness of these coatings in sealing composite tanks, both before and after impact damage, is demonstrated. Fuel and water permeability data are presented. Rapid cure characteristics are also illustrated making these coatings of particular value for production lines. Coating procedures for sealing disposable or integral fuel tanks without use of faying surface sealants are discussed. Results on adhesion to metals, composites and conventional aerospace sealants are presented. Ease of repair, surface preparation and product application are also discussed when sealing simple or complex fuel tanks. The chemistry of polythioether polyurethane polymers is also discussed and compared to conventional polyurethane materials, illustrating how these new coatings provide a new dimension in aircraft sealing technology.

Author

## 12

### ENGINEERING

Includes engineering (general); communications; electronics and electrical engineering; fluid mechanics and heat transfer; instrumentation and photography; lasers and masers; mechanical engineering; quality assurance and reliability; and structural mechanics.

**A90-20065**

**SIGNIFICANCE OF THE SHORT CRACK EFFECT ON AEROSPACE STRUCTURES**

JAMES A. HARTER, CHRISTOPHER J. MAZUR, DOUGLAS R. MILLER (USAF, Flight Dynamics Laboratory, Wright-Patterson AFB, OH), and JOSEPH P. NALEPKA /In: International Congress on Experimental Mechanics, 6th, Portland, OR, June 6-10, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 858-865. refs

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The effects of short cracks on current durability and damage tolerance analyses for fixed and rotary wing aircraft structures are

examined. An analytical comparison is performed using short and long crack data together with experimental results from the plastic replica method. The results indicate that the benefits of using short crack growth rate data are minimal for cracks on the order of 1.27 mm. The effect is greater for shorter cracks, but appears to be relatively minor for the tested cases. C.D.

## A90-20077

### THREE DIMENSIONAL PHOTOELASTIC ANALYSIS OF AEROENGINE PARTS

H. AONO, T. KAWASHIMA, and T. TANAKA (Ishikawajima-Harima Heavy Industries Co., Ltd., Tokyo, Japan) IN: International Congress on Experimental Mechanics, 6th, Portland, OR, June 6-10, 1988, Proceedings. Volume 2. Bethel, CT, Society for Experimental Mechanics, Inc., 1988, p. 1055-1060. refs Copyright

The role of three-dimensional photoelasticity in the design of modern aerogas turbine engine parts is addressed. An example is used to show that the three-dimensional photoelastic stress freezing technique will play an important role in modifying a finite element analysis method used in aerogas turbine engine design. The advantages of the photoelastic techniques are evaluated. C.D.

## A90-20264

### RESIN TRANSFER MOLDING OF COMPOSITE STRUCTURES

Aerospace Engineering (ISSN 0736-2536), vol. 9, Dec. 1989, p. 23-26. Copyright

In certain aerospace composite structures, the use of resin-transfer molding (RTM) may help lower manufacturing costs. RTM involves a fiber-reinforcement preform's placing inside a closed mold into which resin will be injected at pressures below 690 kPa. The resulting molded structure is mold-controlled on all sides and involves neither bagging labor nor bagging material waste. In addition, inserts, ribs, bosses, and cores can be molded in place. Since fiber loadings can range from zero to 70 wt pct, both primary and secondary airframe structures can be molded to specific requirements. O.C.

## A90-20426

### STABILITY AND VIBRATIONS OF MECHANICAL SYSTEMS [USTOICHIVOST' I KOLEBANIYA MEKHANICHESKIKH SISTEM]

P. E. TOVSTIK, ED. (Leningradskii Gosudarstvennyi Universitet, Leningrad, USSR) Leningrad, Izdatel'stvo Leningradskogo Universiteta (Prikladnaia Mekhanika, No. 7), 1988, 252 p. In Russian. For individual items see A90-20427 to A90-20444. Copyright

The papers contained in this volume deal with a variety of problems in the theory of vibrations and motion stability and in automatic control theory. Topics discussed include linear and nonlinear vibrations and stability of mechanical and electromechanical systems, rotational motion of artificial earth satellites, and the elastic vibrations and stability of rods and shells. Papers are presented on forced vibrations in an electromechanical system; impact of a ring against a beam; vibrations of a wing of nonzero thickness in supersonic flow; and effect of the nonuniform rotation of the gas turbine rotor on blade vibrations. V.L.

## A90-20599

### APPLICATION OF THE DYNAMIC STIFFNESS METHOD TO THE FREE AND FORCED VIBRATIONS OF AIRCRAFT PANELS

R. S. LANGLEY (Cranfield Institute of Technology, England) Journal of Sound and Vibration (ISSN 0022-460X), vol. 135, Dec. 8, 1989, p. 319-331. refs Copyright

The free and forced vibrations of a row of rectangular panels which are stiffened transversely and simply supported along the longitudinal edges is considered. The equations of motion of the component parts are derived by using a dynamic stiffness formulation, which enables the standard techniques of the FEM

to be applied to the assembly. Expressions are derived for the mean power flow through the system and the mean energy which is stored in the component parts. The method is applied to a single panel, a six-panel row, and an infinite-panel row. Author

## A90-20608

### HELICOPTER TRANSMISSIONS - DESIGN FOR SAFETY AND RELIABILITY

D. G. ASTRIDGE (Seminar on Design of Aerospace Transmissions, Taunton, England, Mar. 29, 1988) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100), vol. 203, no. G2, 1989, p. 123-138. refs Copyright

An analysis of the UK CAA's world-wide helicopter accident data has indicated that transmissions accounted for 22 percent of potentially airworthiness-related accidents in civil helicopters of more than 4550 kg gross weight. An evaluation is made of design and technology advancements over the last decade which should benefit helicopter transmission safety and reliability. These encompass improved steels with superior fatigue performance, S/N curve refinement, computer-aided design/analysis systems, CAD/CAM, improved lubricants and filtration systems, and expert systems retaining a 'collective memory' with regard to design practices' relationship to service experience. O.C.

## A90-20609

### A COMPUTER AIDED MANUFACTURING PROCEDURE FOR EXPERIMENTAL TWO-DIMENSIONAL AEROFOILS

H. H. AL-KAYIEM (MEC, Baghdad, Iraq), A. J. DAY, and H. H. BRUUN (Bradford, University, England) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100), vol. 203, no. G2, 1989, p. 139-144. refs Copyright

This paper describes a computer aided manufacturing procedure that has been developed for the production, in a small research engineering workshop, of experimental wing models required for investigation of the separation of flow from an NACA 4412 airfoil section. A 2-1/2 axis computerized numerical control vertical milling machine has been programmed, with coordinates generated by computer from the NACA 4412 defined profile, to produce airfoil sections which are then built up into a wing model. The method is fast and accurate, enabling the time and cost of manufacture to be substantially reduced, at the same time improving the accuracy and quality of the model. The procedure has been developed as a computer program and is also used as a case study teaching aid in computer-aided manufacture. Author

## A90-20770

### OPTIMUM DESIGN OF ROTATIONAL WHEELS UNDER TRANSIENT THERMAL AND CENTRIFUGAL LOADING

TOSHIO HATTORI and HIROO OHNISHI (Hitachi, Ltd., Mechanical Engineering Research Laboratory, Tsuchiura, Japan) JSME International Journal, Series III (ISSN 0914-8825), vol. 32, Dec. 1989, p. 597-605. refs Copyright

An optimum design system for turbine and compressor rotors is developed which offers the lightest possible wheel shape under a bearing load-limit restriction. The sequential linear programming method is used in the optimization process, and unsteady-state thermal analysis of variable-thickness wheels is performed by numerical analysis of a multiring model. Centrifugal and thermal stress analyses of these wheels are performed using Donath's method with the same multiring model. This optimum design program is applied to the design of axial flow compressor wheels. The validity of these results is confirmed by transient thermal and stress analyses using the finite element method. S.A.V.

## A90-20987

### FATIGUE OF THICK-SECTION COLD-EXPANDED HOLES WITH AND WITHOUT CRACKS

R. A. PELL, P. W. BEAVER, J. Y. MANN, and J. G. SPARROW (Department of Defence, Aeronautical Research Laboratory, Port

Melbourne, Australia) **Fatigue and Fracture of Engineering Materials and Structures** (ISSN 8756-758X), vol. 12, no. 6, 1989, p. 553-567. refs  
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Fatigue tests under spectrum loading were conducted to evaluate hole cold-expansion in thick-section open-hole aluminum alloy specimens, some of which contained residual fatigue cracks before cold expansion. Cold expansion resulted in an increase in life by a factor of about 7. Small residual fatigue cracks did not inhibit the effectiveness of the cold-expansion process, indicating that it may not be essential to remove such cracks prior to hole cold-expansion. The increase in life is primarily associated with a reduced crack propagation rate compared with that for cracks from non-cold-expanded holes. Cold-expanded hole fractures displayed a marked disparity in crack depths adjacent to the two faces of the specimens. Considerable differences were evident in crack depths and fatigue crack areas at failure between cold-expanded and non-cold-expanded hole specimens. These findings have ramifications in the damage tolerance assessment of aircraft structures. Author

**A90-21113\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### **EFFICIENCY TESTING OF A HELICOPTER TRANSMISSION PLANETARY REDUCTION STAGE**

R. F. HANDSCHUH (U.S. Army, Propulsion Directorate, Cleveland, OH) and D. A. ROHN (NASA, Lewis Research Center, Cleveland, OH) IN: 1989 International Power Transmission and Gearing Conference, 5th, Chicago, IL, Apr. 25-28, 1989, Proceedings. Volume 1. New York, American Society of Mechanical Engineers, 1989, p. 243-257. Previously announced in STAR as N88-15224. refs

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A parametric study of the efficiency of a 310-kW (420-hp) helicopter transmission planetary test section (four planets) was performed. The purpose was to determine the planetary contribution to the overall transmission power loss. Test parameters varied were oil flow rate, oil inlet temperature, lubricant type, shaft speed, and applied torque. The measured efficiency over all the test variables ranged from 99.44 to 99.75 percent. These experimental results were compared with other experimental and computational results. Author

**A90-21115\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

#### **EFFECT OF ADVANCED COMPONENT TECHNOLOGY ON HELICOPTER TRANSMISSIONS**

D. G. LEWICKI (NASA, Lewis Research Center; U.S. Army, Propulsion Directorate, Cleveland, OH) and D. P. TOWNSEND (NASA, Lewis Research Center, Cleveland, OH) IN: 1989 International Power Transmission and Gearing Conference, 5th, Chicago, IL, Apr. 25-28, 1989, Proceedings. Volume 1. New York, American Society of Mechanical Engineers, 1989, p. 267-279. Previously announced in STAR as N89-13794. refs

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Experimental tests were performed on the NASA/Bell Helicopter Textron (BHT) 500 hp advanced technology transmission (ATT) at the NASA Lewis Research Center. The ATT was a retrofit of the OH-58C helicopter 236 kW (317 hp) main rotor transmission, upgraded to 373 kW (500 hp), with a design goal of retaining long life with a minimum increase in cost, weight, and size. Vibration, strain, efficiency, deflection, and temperature experiments were performed and the results were compared to previous experiments on the OH-58A, OH-58C, and UH-60A transmissions. The high-contact-ratio gears and the cantilevered-mounted, flexible ring gear of the ATT reduced vibration compared to that of the OH-58C. The ATT flexible ring gear improved planetary load sharing compared to that of the rigid ring gear of the UH-60A transmission. The ATT mechanical efficiency was lower than that of the OH-58A transmission, probably due to the high-contact-ratio planetary gears. Author

**A90-21129#**

#### **AN INVESTIGATION OF THE BEHAVIOR OF THE DYNAMIC LOAD DISTRIBUTION VERSUS OPERATING SPEED AND TORQUE ON HEAVILY LOADED, HIGH SPEED AIRCRAFT GEARING**

K. BUYUKATAMAN (GE Aircraft Engines, Lynn, MA) IN: 1989 International Power Transmission and Gearing Conference, 5th, Chicago, IL, Apr. 25-28, 1989, Proceedings. Volume 1. New York, American Society of Mechanical Engineers, 1989, p. 479-488. refs

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A finite element Computer Program has been developed by GE for evaluating Dynamic Load Distributions with their exact point of application for heavily-loaded high speed aircraft type gearing. The method presented here requires system simulation with its attached inertias. Analyses show close correlation between the measured web stress and transmitted dynamic load. An increase in Input Speed beyond the boundaries of critical speed appears to provide smoother load response with reduced peak and increased valleys. The shape of this load response also appears to change with contact ratio in action and with different diametral pitches and with the value of applied loads. Investigation results were compared with previous analytical and experimental studies and with the dynamic factors presented in AGMA 218.01. Author

**A90-21141#**

#### **DEVELOPMENT STATUS OF EPICYCLIC GEARS**

F. JARCHOW (Bochum, Ruhr-Universitaet, Federal Republic of Germany) IN: 1989 International Power Transmission and Gearing Conference, 5th, Chicago, IL, Apr. 25-28, 1989, Proceedings. Volume 2. New York, American Society of Mechanical Engineers, 1989, p. 847-858. refs

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The paper considers recent research results. The subjects discussed include the load distribution among the planet wheels and on the individual teeth, the deformations and stresses of planet wheel carriers, fatigue failures in the cages of planet wheel rolling bearings, the seizure limits of full-type rolling bearings, the power losses associated with planet wheel rolling bearings, the power loss in the teeth of the internal gear and the sun wheel and, finally, the noise produced. Author

**A90-21324**

#### **FINITE ELEMENT ANALYSIS OF NONSTATIONARY TEMPERATURE FIELDS IN GAS TURBINE COMPONENTS [KONECHNOELEMENTNYI ANALIZ NESTATSIONARNYKH POLEI TEMPERATUR V DETALIAKH GTU]**

IU. G. ISPOLOV and N. N. SHABROV (Leningradskii Politehnicheskii Institut, Leningrad, USSR) Problemy Prochnosti (ISSN 0556-171X), Dec. 1989, p. 82-87. In Russian. refs

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A finite element method is proposed for the numerical solution of the nonstationary heat conductivity problem arising in the analysis of the high-temperature strength of the structural elements of power generating equipment. The method has a second degree of accuracy and is absolutely stable. It is shown that the method proposed here has advantages over the traditional methods, such as the Euler and Galerkin methods, in solving stationary heat conduction problems with rapidly varying boundary conditions. V.L.

**A90-21979#**

#### **NUMERICAL CALCULATION OF GASEOUS REACTING FLOWS IN A MODEL OF GAS TURBINE COMBUSTORS**

CHUANJUN YAN, MING TANG, HUILING ZHU, and HUIXIAN SUN (Northwestern Polytechnical University, Xian, People's Republic of China) Acta Aeronautica et Astronautica Sinica (ISSN 1000-6893), vol. 10, Nov. 1989, p. A565-A572. In Chinese, with abstract in English. refs

This paper describes the numerical calculation of gaseous reacting flows in a model gas turbine combustor. The profiles of hydrodynamic and thermodynamic patterns in the model are

obtained by solving the governing differential transport equations. The well-established numerical prediction algorithm, the improved k-epsilon turbulence model, and k-epsilon-g turbulent diffusion flame model have been adopted in computations. The beta function has been selected as probability density function. The effect of combustion process on flow patterns has been investigated. The calculated results have been verified by experiments. Author

**A90-22004#****A STUDY ON INITIAL FATIGUE QUALITY OF TYPICAL AIRCRAFT STRUCTURES (FASTENER HOLES)**

MINBO TONG, MINZHONG ZHENG, JUNYANG WANG (Aircraft Strength Research Institute, People's Republic of China), and CHUANYAO CHEN (Huazhong University of Science and Technology, Wuhan, People's Republic of China) *Acta Aeronautica et Astronautica Sinica* (ISSN 1000-6893), vol. 10, Dec. 1989, p. B595-B600. In Chinese, with abstract in English.

In this paper, an engineering approach for determining initial fatigue quality (IFQ) of aeronautic structure details (fastener holes) is introduced. The equivalent effects of a physical initial flaw on one or multiple structure details are characterized by equivalent initial flaw size (EIFS) distribution. The growth law of this distribution is described by the service crack growth master curve (SCGMC). The damage extent of the detail fatigue cracking is determined by crack exceedance probability. In general, the engineering approach is applied to other structure details such as cutouts, fillets, lugs, etc. A number of tests were conducted and a calculation program for optimizing the parameters were written. By comparing the test results with the calculation results, it is demonstrated that the approach is suitable for durability analysis of aeronautic structures. Author

**A90-22014#****THE APPLICATION OF THE ENGINEERING APPROACH FOR ANALYZING CRACK TOLERANCE OF FUSELAGE PANELS TO A TRANSPORT AIRPLANE**

FUMEI LU, BIN WANG (Aircraft Strength Research Institute, People's Republic of China), and DIQING LIU (Xian Aircraft Co., People's Republic of China) *Acta Aeronautica et Astronautica Sinica* (ISSN 1000-6893), vol. 10, Dec. 1989, p. B653-B658. In Chinese, with abstract in English. refs

In this paper, the stress strength factor of fuselage stiffened panels of transport airplanes are obtained by using a two-dimensional, analytical solution, curvature correction, and nonuniform stress correction. Based on the K(c) criterion, the critical crack length has been obtained. By using the fast integral technique, the residual strength and residual life under random spectra for skin circumferential crack at a typical broken stringer and for longitudinal crack at a typical broken frame are obtained and analyzed. Then, by analyzing the above numerical results, the basic information for determining the life of a transport aircraft has been provided. Due to the use of analytical and fast integral approaches the method used in this paper is convenient and economic. It can be used for crack tolerance analysis of other aircraft structures. Author

**A90-22135****OPTIMUM DESIGN OF COMPOSITE STRUCTURES**

G. N. VANDERPLAATS (VMA Engineering, Goleta, CA) and T. A. WEISSHAAR (Purdue University, West Lafayette, IN) *International Journal for Numerical Methods in Engineering* (ISSN 0029-5981), vol. 27, Sept. 1989, p. 437-448. refs Copyright

The use of numerical optimization techniques in the design of laminated composite structures is discussed in an analytical review. Topics addressed include optimization algorithms; the design of simple and stiffened composite panels using the panel analysis and sizing code PASCO (Stroud and Anderson, 1980) and the integrated interactive package PANDA (Bushnell, 1981); and aeroelastic tailoring using TSO (McCullers and Lynch, 1974). Results for typical problems are presented in extensive graphs and briefly characterized. T.K.

**A90-22180\*#** National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

**CONVECTIVE HEAT TRANSFER MEASUREMENTS FROM A NACA 0012 AIRFOIL IN FLIGHT AND IN THE NASA LEWIS ICING RESEARCH TUNNEL**

PHILIP E. POINSATTE, G. JAMES VAN FOSSEN (NASA, Lewis Research Center, Cleveland, OH), and KENNETH J. DEWITT (Toledo, University, OH) *AIAA, Aerospace Sciences Meeting*, 28th, Reno, NV, Jan. 8-11, 1990. 19 p. Previously announced in STAR as N90-13750. refs

(AIAA PAPER 90-0199) Copyright

Local heat transfer coefficients were measured on a smooth and roughened NACA 0012 airfoil. Heat transfer measurements on the 0.533 m chord airfoil were made both in flight on the NASA Lewis Twin Otter Icing Research Aircraft and in the NASA Icing Research Tunnel (IRT). Roughness was obtained by the attachment of uniform 2 mm diameter hemispheres to the airfoil surface in 4 distinct patterns. Flight data were taken for the smooth and roughened airfoil at various Reynolds numbers based on chord in the range 1.24 to 2.50 x 10 (exp 6) and at various angles of attack up to 4 deg. During these flight tests, the free stream velocity turbulence intensity was found to be very low (less than 0.1 percent). Wind tunnel data were acquired in the Reynolds number range 1.20 to 4.25 x 10 (exp 6) and at angles of attack from -4 to 8 deg. The turbulence intensity in the IRT was 0.5 to 0.7 percent with the cloud generating sprays off. A direct comparison was made between the results obtained in flight and in the IRT. The higher level of turbulence in the IRT vs. flight had little effect on the heat transfer for the lower Reynolds numbers but caused a moderate increase in heat transfer at the high Reynolds numbers. Roughness generally increased the heat transfer. Author

**A90-22182\*#** Analytical Services and Materials, Inc., Hampton, VA.

**A NUMERICAL STUDY OF MIXING ENHANCEMENT IN A SUPERSONIC COMBUSTOR**

D. W. RIGGINS, G. L. MEKKES (Analytical Services and Materials, Inc., Hampton, VA), C. R. MCCLINTON, and J. PHILIP DRUMMOND (NASA, Langley Research Center, Hampton, VA) *AIAA, Aerospace Sciences Meeting*, 28th, Reno, NV, Jan. 8-11, 1990. 17 p. refs (AIAA PAPER 90-0203) Copyright

This investigation describes an application of the Langley Research Center (LaRC) SPARK family of computer codes to swept and unswept ramp fuel injectors in a reacting highly vortical flow. Both mixing and reacting studies are performed. They show substantially higher mixing as well as flow losses for the swept ramp case. Computational results are compared both qualitatively and quantitatively with experimental results. Author

**A90-22265#****CRITICAL EVALUATION OF THREE-DIMENSIONAL SUPERSONIC COMBUSTOR CALCULATIONS**

CHAE M. RHIE (United Technologies Corp., Pratt and Whitney Group, East Hartford, CT) and SAADAT A. SYED (United Technologies Corp., Pratt and Whitney Group, West Palm Beach, FL) *AIAA, Aerospace Sciences Meeting*, 28th, Reno, NV, Jan. 8-11, 1990. 11 p. refs

(AIAA PAPER 90-0207) Copyright

A nonreacting supersonic combustor case is studied with a Navier-Stokes CFD code using a k - epsilon two-equation turbulence model. The numerical scheme is based on a pressure correction algorithm solving the Full Navier-Stokes equations. The present combustor test section is configured with staged, transverse injectors located behind a rearward-facing step. The effect of the turbulent Schmidt number on mixing, penetration, and spreading rates associated with transverse injection is extensively investigated by comparing calculations with experimental data. Author

**A90-22529****EVALUATION AND MEASUREMENT OF AIRPLANE FLUTTER INTERFERENCE**

HIROSHI MIYAZAWA (Japan Broadcasting Corp., Receiving Engineering Center, Tokyo) IEEE Transactions on Broadcasting (ISSN 0018-9316), vol. 35, Dec. 1989, p. 362-367. refs  
Copyright

Aircraft flutter interference is picture disturbance in television reception caused by signals reflected off passing aircraft. Through indoor testing, the relationship between physical factors affecting aircraft flutter and its subjective evaluation was analyzed. The factors necessary for flutter measurement as well as their range of influence are discussed. A method that was developed for measuring the physical amount of flutter is described. The method was confirmed through tests made near an airport using prototype test equipment. I.E.

**A90-22651\*** # California Univ., Irvine.

**INFLUENCE OF THE CONTINUOUS AND DISPERSED PHASES ON THE SYMMETRY OF A GAS TURBINE AIR-BLAST ATOMIZER**

V. G. MCDONELL and G. S. SAMUELSEN (California, University, Irvine) ASME, Transactions, Journal of Engineering for Gas Turbines and Power (ISSN 0022-0825), vol. 112, Jan. 1990, p. 44-51. Research supported by General Motors Corp. refs  
(Contract NAS3-24350)  
(ASME PAPER 89-GT-303) Copyright

Current trends in liquid-fueled practical combustion systems are leaving less tolerance for fuel injection deficiencies such as poor spray field symmetry. The present paper evaluates the symmetry of the flowfield produced by a practical airblast atomizer. Specifically, the influence of both the continuous phase and dispersed phase on the spray field symmetry is assessed. In the present case, asymmetry in volume flux is associated principally with disparities in the injection of the dispersed phase, which is manifested by a maldistribution of larger drops. Asymmetries observed in the continuous phase without the dispersed phase are reduced in magnitude by the presence of the dispersed phase, but still contribute to asymmetry in radial spread of the dispersed phase. Author

**A90-22663#**

**EXPERIMENTAL AND THEORETICAL STUDY OF THE SWIRLING FLOW IN CENTRIFUGAL COMPRESSOR VOLUTES**

R. A. VAN DEN BRAEMBUSSCHE and B. M. HAENDE (Institut von Karman de Dynamique des Fluides, Rhode-Saint-Genese, Belgium) ASME, Transactions, Journal of Turbomachinery (ISSN 0889-504X), vol. 112, Jan. 1990, p. 38-43. refs  
(ASME PAPER 89-GT-183) Copyright

Measurements of the three-dimensional flow in a simplified model of a centrifugal compressor volute at design and off-design operation are presented. A nearly constant swirl velocity is observed near the walls and a forced vortex type of flow is observed in the center. This velocity distribution is almost identical at all cross sections and all operating points. An explanation is given on how this swirl distribution results from the specific way a volute is filled with fluid. The throughflow velocity component shows a large crosswise variation. A minimum or maximum velocity is observed at the volute center depending on the operating point. A simple analytic model, based on the radial equilibrium of forces, is described. Calculations for isentropic flows reveal the relation between the swirl distribution and the large increase of throughflow velocity toward the center. This explains why volutes should be designed with negative blockage. Nonisentropic calculations, using the experimental loss distribution, correctly reproduce the measured throughflow velocity and static pressure distribution. Author

**A90-22743**

**HANDBOOK ON HEAT EXCHANGERS [SPRAVOCHNIK PO TEPLIOBMENNYYM APPARATAM]**

PAVEL I. BAZHAN, GEORGII E. KANEVETS, and VLADIMIR M. SELIVERSTOV Moscow, Izdatel'stvo Mashinostroenie, 1989, 368 p. In Russian. refs  
Copyright

Essential data on heat exchange equipment used in ship, locomotive, automotive, and aircraft powerplants are presented in

a systematic manner. The data cover the principal types and technical and performance characteristics of heat exchangers, fundamentals of the theory of heat exchange, calculation of heat transfer coefficients for different types of heat exchange apparatus, optimization of heat exchangers, computer-aided design of heat exchange equipment, testing techniques, and test result processing. V.L.

**A90-23013\*** Aerostructures, Inc., Arlington, VA.

**FINITE ELEMENT MESH REFINEMENT CRITERIA FOR STRESS ANALYSIS**

MADAN G. KITTUR (Aerostructures, Inc., Arlington, VA) and RONALD L. HUSTON (Cincinnati, University, OH) Computers and Structures (ISSN 0045-7949), vol. 34, no. 2, 1990, p. 251-255. refs  
(Contract NSG-3188)  
Copyright

This paper discusses procedures for finite-element mesh selection and refinement. The objective is to improve accuracy. The procedures are based on (1) the minimization of the stiffness matrix race (optimizing node location); (2) the use of h-version refinement (rezone, element size reduction, and increasing the number of elements); and (3) the use of p-version refinement (increasing the order of polynomial approximation of the elements). A step-by-step procedure of mesh selection, improvement, and refinement is presented. The criteria for 'goodness' of a mesh are based on strain energy, displacement, and stress values at selected critical points of a structure. An analysis of an aircraft lug problem is presented as an example. Author

**A90-23207**

**STRUCTURE OF VELOCITY AND TEMPERATURE FIELDS IN LAMINAR CHANNEL FLOWS WITH LONGITUDINAL VORTEX GENERATORS**

M. FIEGIB, U. BROCKMEIER, N. K. MITRA, and T. GUENTERMANN (Bochum, Ruhr-Universitaet, Federal Republic of Germany) Numerical Heat Transfer, Part A: Applications (ISSN 1040-7782), vol. 15, no. 3, 1989, p. 281-302. refs  
Copyright

Laminar velocity and temperature fields in a rectangular channel with a row of built-in vortex generators in the form of slender delta wings and winglet pairs have been calculated by means of a zonal method consisting of zones of complete and partially parabolized Navier-Stokes and energy equations. A modified version of SOLA for incompressible as well as for variable-density, small-Mach number flows has been used to solve the basic equations. Each wing or winglet pair generates counterrotating longitudinal vortices that, in contrast to similar vortices in an unbounded medium, show an elliptic deformation, a wakelike axial velocity distribution in the core, and an absence of breakdown even at angles of attack as large as 50 deg. The spiraling motion induced by these vortices in the channel can locally enhance the heat transfer coefficient by a factor of 3 compared to its value in a wingless channel. The temperature dependence of density can reduce this enhancement by roughly 10 percent when the ratio of gas-to-wall temperature is 1.3. Author

**A90-23287#**

**DEMONSTRATION OF PROBABILISTIC-BASED DURABILITY ANALYSIS METHOD FOR METALLIC AIRFRAMES**

J. N. YANG (George Washington University, Washington, DC) and S. D. MANNING (General Dynamics Corp., Fort Worth, TX) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 169-175. refs  
(Contract F33615-94-C-3208)  
Copyright

Two different variations of a probabilistic-based durability analysis method are demonstrated and evaluated for countersunk fastener holes in the lower wing skin (7475-T7351 aluminum) of a fighter aircraft. The initial fatigue quality of the fastener holes is represented by an equivalent initial flaw size (EIFS) distribution. Probability of crack exceedance predictions at any service time are based on an EIFS distribution and two different service crack

growth approaches. The service crack growth is divided into two segments. Segment 1 covers the small crack size region (e.g., of less than 1.27 mm) and segment 2 the large crack size region (e.g., above 1.27 mm). Approach I treats the service crack growth as deterministic for both segments. In approach II, the service crack growth is treated as deterministic in segment 1 and stochastic in segment 2. Analytical predictions for the extent of damage (i.e., number of fastener holes exceeding specified sizes), based on approaches I and II, are compared and correlated with experimental results. Good correlations are obtained for both approaches. Approach II was found to be more conservative than approach I.

Author

#### A90-23353

##### FATIGUE TESTS OF SAMPLES OF FLANGED JOINTS OF WINGS [UNAVOVE ZKOUSKY VZORKU PRIRUBOVEHO SPOJE KRIDLÁ]

VACLAV KAHANEK Zpravodaj VZLU (ISSN 0044-5355), no. 4, 1989, p. 197-202. In Czech.

Copyright

The paper presents results of fatigue tests of samples of wing panels connected with flanged joints in spliced wing systems. The spliced technology is shown to be inferior to other types of joints from the viewpoint of fatigue.

B.J.

#### A90-23402

##### PREDICTION OF THE STRENGTH-RELATED RELIABILITY OF STRUCTURAL ELEMENTS AT THE DESIGN STAGE

##### [PROGNOZIROVANIE PROCHNOSTNOI NADEZHNOСТИ ELEMENŤOV KONSTRUKTSII NA ETAPE PROEKTIROVANIJA]

V. M. DUPLIAKIN, T. D. KOVALENKO, and S. N. PEROV Aviatsonnaia Tekhnika (ISSN 0579-2975), no. 4, 1989, p. 5-8. In Russian. refs

Copyright

Methods are proposed for calculating the probability of the avoidance of sudden and gradual failures in load-bearing structural elements. The mechanical reliability of structural elements is estimated on the basis of the weak-link statistical theory of fatigue fracture. Calculations of the probability of failure-free operation are presented for structural elements made of AMg6M, MA2-1, and 1Kh18N9T alloys.

V.L.

#### A90-23686

##### AIR FORCE APPLICATION OF INJECTION MOLDING TECHNOLOGY

DENNIS TANG and CHRISTOPHER L. FRANK (USAF, Advanced Composites Program Office, Sacramento, CA) Society of Manufacturing Engineers, Conference on Composites in Manufacturing 8, Anaheim, CA, Jan. 9-12, 1989. 14 p. (SME PAPER EM89-103) Copyright

The USAF Advanced Composites Program Office has developed an in-house capability for the design and prototype development of thermoplastic resin-based, injection-molded structural components in applications which have been judged capable of exhibiting substantial performance, reliability, and acquisition cost improvements as a result of fabrication by these means. State-of-the-art CAD/CAM equipment is employed throughout, in conjunction with a 1500-ton injection molding apparatus. Illustrative examples of prototype components developed to date encompass airframe secondary structures, cockpit components, electronic equipment enclosures, and ground support components.

O.C.

#### A90-23694

##### ADVANCED SOFTWARE FOR TURBINE BLADE PROCESSING

VERNON L. MANGOLD, JR. (Kohol Systems, Inc., Dayton, OH) Society of Manufacturing Engineers, Conference on Robots 13, Gaithersburg, MD, May 7-11, 1989. 8 p. (SME PAPER MS89-330) Copyright

The weighing and sorting of unshrouded turbine blades prior to rotor assembly entails both real-time, in-process inspection and postprocess control. An account is presently given of the machine control, robot-programming, and host computer application software and communication software involved in the successful realization

of an automated turbine blade-sorting system. The system employs an off-the-shelf freestanding robot to maximize processing flexibility.

O.C.

A90-23702\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

##### THERMAL/STRUCTURAL ANALYSES OF SEVERAL HYDROGEN-COOLED LEADING-EDGE CONCEPTS FOR HYPERSONIC FLIGHT VEHICLES

HERBERT J. GLADDEN, MATTHEW E. MELIS, THEODORE T. MOCKLER, and MIKE TONG (NASA, Lewis Research Center, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 15 p. Previously announced in STAR as N90-14511. refs

(AIAA PAPER 90-0053) Copyright

The aerodynamic heating at high flight Mach numbers, when shock interference heating is included, can be extremely high and can exceed the capability of most conventional metallic and potential ceramic materials available. Numerical analyses of the heat transfer and thermal stresses are performed on three actively cooled leading-edge geometries (models) made of three different materials to address the issue of survivability in a hostile environment. These analyses show a mixture of results from one configuration to the next. Results for each configuration are presented and discussed. Combinations of enhanced internal film coefficients and high material thermal conductivity of copper and tungsten are predicted to maintain the maximum wall temperature for each concept within acceptable operating limits. The exception is the TD nickel material which is predicted to melt for most cases. The wide range of internal impingement film coefficients (based on correlations) for these conditions can lead to a significant uncertainty in expected leading-edge wall temperatures. The equivalent plastic strain, inherent in each configuration which results from the high thermal gradients, indicates a need for further cyclic analysis to determine component life.

Author

A90-23711\*# National Aeronautics and Space Administration. Lewis Research Center, Cleveland, OH.

##### COMPARISON OF TWO DROPLET SIZING SYSTEMS IN AN ICING WIND TUNNEL

JOHN R. OLDENBURG (NASA, Lewis Research Center, Cleveland, OH) and ROBERT F. IDE (NASA, Lewis Research Center; U.S. Army, Aviation Research and Technology Activity, Cleveland, OH) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 18 p. Previously announced in STAR as N90-14617. refs (AIAA PAPER 90-0668) Copyright

A comparison between the Phase Doppler Analyzer and the combined measurements from the Particle Measuring Systems Forward Scattering Spectrometer Probe and the Optical Array Probe was conducted in an icing wind tunnel using NASA Icing Research Tunnel spray nozzles to produce the icing cloud. Clouds with a range of volume median diameters from 10 to greater than 50 microns were used for the instrument comparisons. A comparison of the volume median diameter from the Phase Doppler Particle Analyzer and only the Forward Scattering Spectrometer Probe indicated agreement up to 18 microns. A combined volume median diameter was calculated from the droplet distribution of the Optical Array Probe and the Forward Scattering Spectrometer Probe. A comparison of the combined volume median diameters and the Phase Doppler Particle Analyzer volume median diameters showed agreement up to 30 microns with the agreement deteriorating rapidly above 30 microns. Droplet distributions from the Phase Doppler Particle Analyzer, the Forward Scattering Spectrometer Probe, and Optical Array Probe are presented.

Author

N90-15310# Defence and Civil Inst. of Environmental Medicine, Downsview (Ontario).

##### THE APPLICATION OF QUEUEING THEORY TO THE MODELLING OF CP-140 AIRCRAFT COMMUNICATIONS

E. L. CAMPBELL Jun. 1989 39 p (AD-A213479; DCIEM-89-TR-23) Avail: NTIS HC A03/MF A01 CSCL 12/4



Several authors have argued that queueing models can be used to predict workload and performance of operators under the single channel hypothesis of man's information processing capability. A simple exponential, single server queueing model is used to investigate the application of queueing theory to communication and navigation tasks performed aboard the CP-140 Aurora aircraft. It was anticipated that the model would provide insight into how individual tasks with low workloads combine to create high workload situations. The results, however, indicated problems originating from the data and the model. A new model was recommended as well as an appropriate data collection technique for the application of queueing theory to multi-task situations. GRA

**N90-15380\*** Notre Dame Univ., IN. Aerodynamics Lab.  
**EXPERIMENTAL MEASUREMENTS OF THE LAMINAR SEPARATION BUBBLE ON AN EPPLER 387 AIRFOIL AT LOW REYNOLDS NUMBERS** Final Report, 1 Sep. 1988 - 31 Dec. 1989

GREGORY M. COLE and THOMAS J. MUELLER Jan. 1990 149 p  
 (Contract NSG-1419)  
 (NASA-CR-186263; NAS 1.26:186263; UNDAS-1419-FR) Avail: NTIS HC A07/MF A01 CSCL 20/4

An experimental investigation was conducted to measure the flow velocity in the boundary layer of an Eppler 387 airfoil. In particular, the laminar separation bubble that this airfoil exhibits at low Reynolds numbers was the focus. Single component laser Doppler velocimetry data were obtained at a Reynolds number of 100,000 at an angle of attack of 2.0 degree. Static Pressure and flow visualization data for the Eppler 387 airfoil were also obtained. The difficulty in obtaining accurate experimental measurements at low Reynolds numbers is addressed. Laser Doppler velocimetry boundary layer data for the NACA 663-018 airfoil at a Reynolds number of 160,000 and angle of attack of 12 degree is also presented. Author

**N90-15390#** Air Force Inst. of Tech., Wright-Patterson AFB, OH. School of Engineering.  
**SOLUTION OF POTENTIAL FLOW PAST AN ELASTIC BODY USING THE BOUNDARY ELEMENT TECHNIQUE** M.S. Thesis  
 NORMA F. TAYLOR Dec. 1988 128 p  
 (AD-A213843; AFIT/GAE/AA/88D-37) Avail: NTIS HC A07/MF A01 CSCL 20/4

This thesis describes the development of a Fortran computer code which models the interaction between an incompressible, potential flow and a homogeneous, elastic structure. The boundary element technique was chosen because of its ability to numerically approximate both the fluid and structural behavior with a common definition of the fluid/structure boundary. The ability to accurately model solid and fluid boundaries can be quite important in the fields of aeroelasticity and structural analysis. The nature of these boundaries is what determines the final solution to a problem of fluid flow past an elastic body. Often the complexity of defining and tracking the boundary and its associated boundary conditions has led the user to assumptions of rigid bodies, and therefore rigid boundaries. Certainly the tasks of defining the domain grids for finite difference and finite element techniques have not simplified this process. In the computer code developed for this thesis the fluid and structural governing equations are simultaneously solved to determine the pressure about the structure and the corresponding elastic deformations. The deformations are applied to the original boundary, resulting in a new geometry. This new geometry is used to recalculate the pressure field about the structure, and the process is iterated until a final steady-state solution is obtained. GRA

**N90-15422#** Air Force Systems Command, Wright-Patterson AFB, OH. Foreign Technology Div.  
**CHINA-BUILT AIRBORNE SYNCHRONOUS LASER RANGER THE NEW L-8 JET TRAINER AIRCRAFT**  
 CHANG SHAN SU 1 Sep. 1989 9 p Transl. into ENGLISH

from Guoji Hangkong, (China), no. 3, Mar. 1988 p 56  
 (AD-A213835; FTD-ID(RS)T-0221-89) Avail: NTIS HC A02/MF A01 CSCL 15/3

The airborne synchronous laser ranger designed and built by the China Aviation Technology Import Export Corporation Electrooptics Equipment Research Institute passed flight testing and in September of 1987 was evaluated for design model technology in Luoyang in Honan Province. This ranger is mainly used in attack aircraft for air-to-ground ranging. It provides highly accurate target distance and location information for the fire control systems, improving the firing accuracy of airborne weapons systems. It can also be used in bombers and armed helicopters as well as surface vessels and vehicles for fire control system ranging. It can also be used in combination with aerial cartography, terrain avoidance and terrain allowing systems. GRA

**N90-15465#** Maryland Univ., College Park. Inst. for Advanced Computer Studies.

**INTEGRATED APPROACH FAULT TOLERANCE-CURRENT STATE AND FUTURE REQUIREMENTS** Final Report  
 PANKAJ JALOTE, comp. and SATISH K. TRIPATHI, comp. 1989 19 p  
 (Contract N00014-89-J-1867)  
 (AD-A214402) Avail: NTIS HC A03/MF A01 CSCL 12/5

Fault tolerance is a very broad topic. There are many valuable results in the area with many important areas of research remaining. This workshop brought together researchers in four areas; applications, operating systems, hardware, and modelling, in an attempt to take an integrated view of fault tolerance. The outcome is presented of the discussion of the different groups, and a description of the presentations made at the start of the workshop. The use of computers in critical applications such as aircraft flight control and industrial processes continues to increase. As it does so, there is a corresponding increase in the need for computing systems that will continue to operate despite failures. Perhaps the best approach for achieving such dependable computing is the use of integrated fault tolerance, where the system is designed from the ground up to support dependable computing for the given application. With a clean slate, the system designer can allocate portions of the functionality required to implement dependability to the different levels of the system rather than being forced a priori to use a given architecture or operating system. It is with this view that a workshop was organized to discuss the issues involved in an integrated approach to fault tolerance. GRA

**N90-15486#** Air Force Wright Research and Development Center, Wright-Patterson AFB, OH. Materials Lab.

**PROCEEDINGS OF THE 1988 STRUCTURAL INTEGRITY PROGRAM CONFERENCE** Final Report

THOMAS D. COOPER, ed. and JOHN W. LINCOLN, ed. May 1989 958 p Conference held in San Antonio, TX, 29 Nov. - 1 Dec. 1988  
 (Contract AF PROJ. 2418)  
 (AD-A213545; WRDC-TR-89-4071) Avail: NTIS HC A99/MF A04 CSCL 11/6

A compilation of the papers presented at the 1988 Structural Integrity Program Conference is presented. Some topics of discussion include: Propulsion and Power System Integrity; The Integrity Process as Applied to the F-119-PW-100 Advanced Tactical Fighter Engine; Structural Analysis, Fasteners and Testing; Predicting Fatigue Crack Growth Under Combined Tension and Out of Plane Bending in Transitional Thickness Plates; Inspection of Fatigue Critical Fastener Holes Using Capacitance Measurement System Equipment; An update on the Study of the Quality of Screw Threaded Products; CF116 Full Scale Durability and Damage Tolerance Test; F-16 Full Scale Airframe Durability Test; T37B Damage Tolerance Analysis Results; The C-17 Aircraft Structural Integrity Overview; The X-30 Structural Integrity Program; Structural Risk Analysis in Aging Aircraft Fleets; Metallic/Composite Structures; and Low Velocity Impact Damage Detector Development. GRA

**N90-15912#** Air Force Wright Aeronautical Labs., Wright-Patterson AFB, OH.

**SPRAY SEALING: A BREAKTHROUGH IN INTEGRAL FUEL TANK SEALING TECHNOLOGY**

MARTIN D. RICHARDSON and J. H. ZADARNOWSKI (McDonnell Aircraft Co., Saint Louis, MO.) *In* AGARD, Fuel Tank Technology 12 p Nov. 1988

Copyright Avail: NTIS HC A08/MF A01; Non-NATO Nationals requests available only from AGARD/Scientific Publications Executive

In a continuing effort to increase readiness, a new approach to sealing integral fuel tanks is being developed. The technique seals potential leak sources by spraying elastomeric materials inside the tank cavity. Laboratory evaluations project an increase in aircraft supportability and reliability, an improved maintainability, decreasing acquisition and life cycle costs. Increased usable fuel volume and lower weight than conventional bladders improve performance. Concept feasibility was demonstrated on sub-scale aircraft fuel tanks. Materials were selected by testing sprayable elastomers in a fuel tank environment. Chemical stability, mechanical properties, and dynamic durability of the elastomer are being evaluated at the laboratory level and in sub-scale and full scale aircraft component fatigue tests. The self sealing capability of sprayable materials is also under development. Ballistic tests show an improved aircraft survivability, due in part to the elastomer's mechanical properties and its ability to damp vibrations. New application equipment, system removal, and repair methods are being investigated. Author

**N90-16169#** Deutsche Gesellschaft fuer Luft- und Raumfahrt, Bonn (Germany, F.R.). Arbeitsgemeinschaft Stroemungen mit Abloesung.

**FLOWS WITH SEPARATION**

1988 394 p Partly in ENGLISH and GERMAN The 6th DGLR-Fach-Symposium was held in Brunswick, Fed. Republic of Germany, 8-10 Nov. 1988 Sponsored by BMFT, Bonn, Fed. Republic of Germany (DGLR-PAPERS-88-05; ISBN-3-922010-42-3; ETN-90-95008) Avail: NTIS HC A17/MF A03

Eleven contributions treat the laminar flow behavior of aircraft, a subject of utmost importance for future passenger aircrafts, with emphasis on phenomenology and the prediction of laminar-turbulent transition. Seven contributions treat flow separation on slim delta wings in subsonic flow and at large angles of attack. Ten contributions present numerical calculation methods: further development of boundary layer methods, improved turbulence models, consideration of curvature, solving Navier-Stokes equations. The Hermes development program is presented. ESA

**N90-16170#** Deutsche Gesellschaft fuer Luft- und Raumfahrt, Bonn (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.

**EXPERIMENTS ON THE LAMINAR-TURBULENT TRANSITION ON SWEEP WINGS [EXPERIMENTE ZUM UMSCHLAG LAMINAR-TURBULENT AM SCHIEBENDEN FLUEGEL]**

H. BIPPES and B. MUELLER *In its* Flows with Separation p 3-16 1988 In GERMAN Avail: NTIS HC A17/MF A03

Some basic experiments were conducted for the investigation of the laminar-turbulent transition on swept wings, in connection with theoretical work. The geometry of the models was selected in such a way that each time a single instability mechanism is dominant. The neighborhood of the leading edge is found to be the most complicated region. Preliminary tests on a wing with a concavely curved profile part show that such surfaces are very unstable, even in three dimensional boundary layers. With respect to cross flow instability the nonlinear domain of the continuous excitation of the boundary layer was analyzed; this instability is dominant in three dimensional boundary layers, in contrast with predictions of linear stability theory. Wind tunnel experiments at

different degrees of turbulence show complicated correlations between initial perturbations and transition in three dimensional boundary layers. ESA

**N90-16172#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport- und Verkehrsflugzeuge. **AN EFFICIENT SOLVER OF THE EIGENVALUE PROBLEM OF THE LINEAR STABILITY EQUATIONS FOR THREE DIMENSIONAL, COMPRESSIBLE BOUNDARY-LAYER FLOWS** GEZA SCHRAUF *In* DGLR, Flows with Separation p 27-38 1988

Avail: NTIS HC A17/MF A03

A compressible stability code was developed as a tool for the design of natural-laminar-flow airfoils. The code is based on a general set of stability equations which allows one to examine the influence of non-parallelity or non-zero pressure gradients. It also allows streamline and surface curvature to be included. ESA

**N90-16174#** Technische Hochschule, Darmstadt (Germany, F.R.). Fachgebiet Aerodynamik und Messtechnik.

**SEMI-EMPIRICAL TRANSITION CRITERIA FOR THE DESIGN OF LAMINAR PROFILES [SEMI-EMPIRISCHE TRANSITIONSKRITERIEN FUEER DEN ENTWURF VON LAMINARPROFILIEN]**

S. STROH and P. THIEDE (Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen, Germany, F.R.) *In* DGLR, Flows with Separation p 41-53 1988 In GERMAN

Avail: NTIS HC A17/MF A03

Laminar-turbulent transition predictions were made, with a view to the reliable design of laminar flow airfoils. The primary instability and the length of the excitation region were universally calculated for the solutions of the compressible boundary equations. This data base was used for the establishment of a simplified transition criterium for compressible profile boundary layers. Test calculations for incompressible and compressible profile flows show good agreement with measurements and linear stability calculations. The transition prediction is better, the more precisely the condition of constant pressure gradient in the excitation region is fulfilled. The criterium is especially suited for the design of laminar profiles. ESA

**N90-16175#** Technische Univ., Berlin (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.

**DETECTION OF FLOW INSTABILITIES AT AIRFOIL PROFILES USING PIEZOELECTRIC ARRAYS [DETEKTION VON STROEMUNGINSTABILITAETEN AN TRAGFLUEGELPROFILIEN MIT HILFE VON PIEZO-ARRAYS]**

W. NITSCHKE, P. MIROW, and T. DOERFLER *In* DGLR, Flows with Separation p 55-65 1988 In GERMAN

Avail: NTIS HC A17/MF A03

The possibilities of piezoelectric sensor arrays for the investigation and analysis of laminar-turbulent flow at airfoil profiles, with a view to the characterization of the flow conditions as well as to the detection of flow instabilities in the transition region are discussed. Both wind tunnel tests and free flight tests demonstrated that piezoelectric foil arrays are a valuable and practicable aid in current laminar airfoil research. ESA

**N90-16177#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Entwurfsaerodynamik.

**DETERMINATION OF THE N-FACTOR IN THE BRUNSWICK (FEDERAL REP. OF GERMANY) TRANSONIC WIND TUNNEL USING MEASUREMENTS OF PRESSURE DISTRIBUTIONS AND TRANSITION POINTS, AND THE SALLY METHOD [BESTIMMUNG DES N-FAKTORS IM TRANSSONISCHEN WINDKANAL BRAUNSCHWEIG (TWB) ANHAND VON DRUCKVERTEILUNGS- UND UMSCHLAGPUNKTMESSUNGEN UND DEM SALLY-VERFAHREN]**

H. KOESTER and R. MUELLER *In* DGLR, Flows with Separation p 77-92 1988 In GERMAN

Avail: NTIS HC A17/MF A03

The N-factors (amplitude amplification exponent) of the

Brunswick transonic wind tunnel were determined. The most diverse (mainly laminar) profiles in the Mach number range 0.3 to 0.95 were tested. The transition points were determined using the IR technique, and the pressure distributions were measured, allowing deduction of the N-factors at which the laminar-turbulent boundary layer transition occurs. ESA

**N90-16178#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. fuer Entwurfsaerodynamik.

**DIRECT MEASUREMENT OF LAMINAR INSTABILITY AMPLIFICATION FACTORS IN FLIGHT**

S. J. MILEY, K.-H. HORSTMANN, B. KETTHAUS, C.-P. KRUECKEBERG, and H. WANDERT /in DGLR, Flows with Separation p 93-102 1988

Avail: NTIS HC A17/MF A03

An instrumentation system and methodology were developed to measure the physical parameters of Tollmein-Schlichting (TS) waves on a wing of the LFU 205 research aircraft in flight. Highly position accurate boundary layer traversing mechanisms were used. Probe positioning and data recording were performed under computer software control. Special attention in the software development was given to the research environment of the aircraft cabin. The external disturbance environment was also measured and made available with the TS data. ESA

**N90-16179#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport- und Verkehrsflugzeuge.

**DEVELOPMENT OF TRANSITION CRITERIA ON THE BASIS OF E TO THE N POWER FOR THREE DIMENSIONAL WING BOUNDARY LAYERS [ENTWICKLUNG VON TRANSITIONSKRITERIEN AUF E SUP N BASIS FUER DREIDIMENSIONALE FLUEGELGRENZSCHICHTEN]**

H. BIELER and G. REDEKER (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.) /in DGLR, Flows with Separation p 103-116 1988 In GERMAN

Avail: NTIS HC A17/MF A03

Criteria for the laminar-turbulent transition on laminar flow airfoils were established for wing design purposes. Flight tests with the ATTAS research aircraft provided a data base for the experimental determination of N-factors where  $N$  = amplitude amplification exponent. Cross flow instability, Tollmein-Schlichting instability, and attachment line contamination were observed. The IR method provided a global picture of the transition line, without affecting the flow itself. Boundary layer stability analyses using the Orr-Sommerfeld solver SALLY for several flight conditions give N-factor threshold values for the Tollmein-Schlichting and for the cross flow instability. Curvature effects, compressibility effects, and interactions between the disturbances could not be taken into account. ESA

**N90-16180#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

**THE PRECISE CALCULATION OF THE INVISCID LEADING EDGE FLOW ON A LAMINAR AIRFOIL USING SIMPLE METHODS AND VERIFICATION BY MEASUREMENTS ON THE TLF PILOT MODEL [DIE GENAUE BERECHNUNG DER REIBUNGSFREIEN NASENSTROMUNG AM LAMINARFLUEGEL MIT EINFACHEN METHODEN UND VERIFIKATION DURCH MESSUNGEN AM TLF-PILOTMODELL]**

K. D. KLEVENHUSEN, H. JAKOB, K. BECKER, and R. HENKE /in DGLR, Flows with Separation p 129-140 1988 In GERMAN

Avail: NTIS HC A17/MF A03

The inviscid flow on the leading edge of a laminar flow airfoil was calculated using the program package LISWA (locally infinite swept wind analysis), and compared with measurements on a pilot model. It is shown that the flow can be very accurately calculated with LISWA, and can be usefully combined with a more complicated method, such as the three dimensional Euler code. The LISWA results agree very well with experimental results for a supersonic case on the small pilot model without fuselage TLF (transonic laminar flow). The LISWA method allows interpretation of missing

points in a limited series of measurements, avoiding the very expensive use of large models and wind tunnels with a view to stability calculations. ESA

**N90-16181#** Technische Univ., Brunswick (Germany, F.R.). Inst. fuer Stroemungsmechanik.

**WIND TUNNEL INVESTIGATIONS ON THE CONFIGURATION OF THE INTERNATIONAL VORTEX FLOW EXPERIMENT [WINDKANALUNTERSUCHUNGEN AN DER KONFIGURATION DES INTERNATIONALEN VORTEX FLOW EXPERIMENT]**

H.-CHR. OELKER /in DGLR, Flows with Separation p 141-157 1988 In GERMAN

Avail: NTIS HC A17/MF A03

Wind tunnel experiments were performed with a view to the systematic investigation of vortex interferences and the short range coupled canard type configuration international vortex flow experiment on Euler-code validation. The force and pressure distributions resulting from the wind tunnel experiments demonstrate the basic mechanism of the interference between both wings, leading to an increase of the maximum lift coefficient in comparison with wings without canard type configuration. The flow field measurements show that the vortex system coming off the tail unit continues up to behind the wing and can be univocally identified. ESA

**N90-16182#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Experimentelle Stroemungsmechanik.

**FLOW FIELD VISUALIZATION STUDY ON A 65 DEG DELTA WING AT  $M = 0.85$**

KARL-ALOYS BUETEFISCH and K. HARTMANN /in DGLR, Flows with Separation p 159-168 1988 Presented at the 16th ICAS Congress, Jerusalem, Israel, 28 Aug. - 2 Sep. 1988 Submitted for publication

Avail: NTIS HC A17/MF A03

Flow field visualization experiments were performed in a transonic wind tunnel on a delta wing with rounded leading edge as a contribution to the international vortex flow experiment. The aim was to provide a better understanding of the physical behavior of the flow field that is strongly dominated by the formation, development, and decay of vortices. In addition to force, pressure, and velocity measurements the flow was visualized using the laser light sheet and the oil flow technique. The development of the primary and secondary vortex system was observed. Sudden changes of the flow field structure were found. The digital image processing system provided quantitative data on the positions of the vortices. ESA

**N90-16183#** Universitaet der Bundeswehr, Neubiberg (Germany, F.R.). Inst. fuer Luftfahrttechnik und Leichtbau.

**A NONLINEAR VORTEX-LATTICE METHOD FOR THE CALCULATION OF INTERFERENCE EFFECTS BETWEEN FREE VORTEX SHEETS AND WINGS [EIN NICHTLINEARES WIRBELGITTERVERFAHREN ZUR BERECHNUNG VON INTERFERENZEFFekten ZWISCHEN FREIEN WIRBELSCHICHTEN UND TRAGFLAECHEEN]**

R. BEHR and S. WAGNER /in DGLR, Flows with Separation p 169-180 1988 In GERMAN

(Contract DFG-WA-424/3)

Avail: NTIS HC A17/MF A03

A vortex-lattice method for flow calculations on single and coupled airfoils with and without leading edge flow separation is presented. Using a time-dependent procedure, the formation and position of the separated shear sheets in the flow field are determined. The problems due to the induced velocities in the immediate neighborhood of the discretized vortex sheets were solved, allowing examination of strongly rolled up shear sheets that occur especially in leading edge vortices. Wing loading and flow fields are predicted with acceptable accuracy with a relatively small calculation effort, as demonstrated by comparisons with experiments. ESA

**N90-16184#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick (Germany, F.R.). Inst. for Design Aerodynamics.

**RESEARCH ON THREE DIFFERENT EULER'S SCHEMES APPLIED TO A DELTA WING WITH VORTICAL FLOWS**

J. M. A. LONGO /In DGLR, Flows with Separation p 181-193 1988 Prepared in cooperation with MBB GmbH, Bremen, Federal Rep. of Germany

Avail: NTIS HC A17/MF A03

The capability of the numerical solution of the Euler equations to predict vortex flow fields around a sharp leading edge cropped delta wing at moderate to high angles of attack was investigated for subsonic and transonic flow regimes. The solution of the Euler equations discretized on a given grid is independent of the numerical scheme used to solve the Euler equations, and also of the grid topology and the convergence level. Only the numerical dissipation is responsible for the deviation in the solutions. The dominant effect is related to the truncation error, which is drastically reduced by a proper mesh design in places where high flow gradients are expected. The comparison of computed results with experimental data proves that Euler solvers are a valuable engineering tool for total forces prediction including vortex bursting phenomena and vortex-shock wave interaction. ESA

**N90-16185#** Technische Hochschule, Aachen (Germany, F.R.). Inst. fuer Luft- und Raumfahrt.

**FORCE AND MOMENT MEASUREMENTS ON DELTA WINGS IN UNSTEADY FLOW [KRAFT- UND MOMENTENMESSUNGEN AN DELTAFLUEGELN BEI INSTATIONAERER ANSTROMUNG]**

BERND STECKEMETZ /In DGLR, Flows with Separation p 195-207 1988 In GERMAN

Avail: NTIS HC A17/MF A03

Based on flow observations on delta wings in a water tunnel, force and moment measurements were performed for unsteady flow in a subsonic wind tunnel. The influence of an angle of attack disturbance with a fixed delta wing in a gust field and for a wing maneuver was analyzed. Substantial phase shifts in the force and moment balance were found in unsteady flows. A comparison with water tunnel results shows the correlation with the time-dependent bursting of the leading edge vortex. The effects of the flight mechanics derivatives for a delta wing configuration were calculated with a semiempirical approach. Strong effects of the phase shifts occurring in the force and moment balance on the angle of attack oscillation were found. ESA

**N90-16186#** Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Goettingen (Germany, F.R.). Inst. fuer Theoretische Stroemungsmechanik.

**NUMERICAL SIMULATION OF THE LAMINAR AND TURBULENT THREE DIMENSIONAL FLOW ON A DELTA WING WITH SHARP LEADING EDGE [NUMERISCHE SIMULATION DER LAMINAREN UND TURBULENTEN DREIDIMENSIONALEN STROEMUNG UM EINEN DELTAFLUEGEL MIT SCHARFER VORDERKANTE]**

A. HILGENSTOCK /In DGLR, Flows with Separation p 209-220 1988 In GERMAN

Avail: NTIS HC A17/MF A03

The flows about a 65 deg swept delta wing were simulated using a block structured three dimensional Navier-Stokes computer program. The computational grid generation was performed with an algebraic method. Grid refinements reveal the strong sensitivity of the solution to refinement in the direction perpendicular to the surface. The numerical results agree well with experimental data. ESA

**N90-16189#** Universitaet der Bundeswehr, Neubiberg (Germany, F.R.). Inst. fuer Luftfahrttechnik und Leichtbau.

**CALCULATION OF THE FLOW FIELD OF A MULTIBLADE HELICOPTER ROTOR USING A EULER METHOD INCLUDING THE WAKE [BERECHNUNG DES STROEMUNSFELDES EINES MEHRBLAETTRIGEN HUBSCHRAUBERROTORS MIT HILFE EINES EULER-VERFAHRENS UNTER EINBEZIEHUNG DES NACHLAUFES]**

S. WAGNER, E. KRAEMER, and J. HERTEL /In DGLR, Flows with Separation p 243-254 1988 In GERMAN

(Contract BMFT-514-8891-LFF-8440)

Avail: NTIS HC A17/MF A03

A method for the calculation of the subsonic and transonic flow about a multiblade helicopter rotor in hover flight based on the solution of the Euler equations is presented. Blade-vortex interference was taken into account. It is shown that the Euler equations are very well suited for the description of vortex transport, and hence for the treatment of the main problem of a steady rotor flow, i.e., the blade-vortex interference, without the need of an external vortex model. The results agree with measurements on a model rotor, and represent the effects of lattice topology and the distance of the far field boundary on the vortex propagation. ESA

**N90-16190#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.).

**AN INTERACTIVE METHOD FOR THE FLOW CALCULATION OF AIRFOILS WITH LOCAL SEPARATION REGIONS [EIN INTERAKTIVES VERFAHREN ZUR STROEMUNGSBERECHNUNG VON TRAGFLUEGELPROFILIEN MIT LOKALEN ABLOESEGEBIETEN]**

F. ARNOLD, B. SCHALAU, and F. THIELE (Technische Univ., Berlin, Germany, F.R.) /In DGLR, Flows with Separation p 255-266 1988 In GERMAN

Avail: NTIS HC A17/MF A03

The turbulent flow of the airfoil profile NACA4412 for different angles of attack was calculated using an interactive method. The inverse formulation of the applied difference method for the boundary layer flow allows the calculation of local separation regions that occur at the profile trailing edge for large angles of attack and that can propagate up to the wake. The comparison of the results with measurements shows that, depending on the applied turbulence modeling, the interactive method is suitable for the calculation of airfoil flow with local separation region, even in the off-design domain. The calculation effort is substantially less than for Navier-Stokes solvers. ESA

**N90-16191#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport- und Verkehrsflugzeuge.

**CALCULATION OF THE FLAP PROFILE FLOWS WITH SEPARATION BASED ON COUPLED POTENTIAL AND BOUNDARY LAYER SOLUTIONS [BERECHNUNG VON KLAPPENPROFILSTROEMUNGEN MIT ABLOESUNG AUF DER BASIS GEKOPPELTER POTENTIAL- UND GRENZSCHICHTLOESUNGEN]**

G. DARGEL and H. JAKOB /In DGLR, Flows with Separation p 267-278 1988 In GERMAN

Avail: NTIS HC A17/MF A03

A method for the calculation of flap system flows, based on iteratively coupled potential and boundary layer solutions was developed with a view to the design of high lift systems for passenger and transport aircrafts. The inclusion of the wake in the calculation method allows the determination of the interaction between wake and flap flow which is very important for the calculation of the flap pressure distribution. Trailing edge separations were calculated. The calculation of the aerodynamic coefficients was substantially improved and could be extended to stalling. Test calculations show that the modeling of separated turbulent boundary layer flow and wakes and their interaction must be improved. ESA

**N90-16192#** Messerschmitt-Boelkow-Blohm G.m.b.H., Bremen (Germany, F.R.). Transport- und Verkehrsflugzeuge.  
**INVERSE SOLUTIONS FOR BOUNDARY LAYERS' WITH SEPARATION OR CLOSE TO SEPARATION UNDER LOCALLY INFINITE SWEEP WING CONDITIONS [INVERSE LOESUNGEN FUER ABLOESENAHE/ABGELOESTE GRENZSCHICHTEN UNTER LOCALLY INFINITE SWEEP WING BEDINGUNGEN]**  
 E. ELSHOLZ /in DGLR, Flows with Separation p 279-288 1988 In GERMAN  
 Avail: NTIS HC A17/MF A03

An inverse Locally Infinite Swept Wing (LISW) difference method for quasi three dimensional wall and wake boundary layer flows with partial separated flow regions is described. The LISW method solves the Prandtl boundary layer equations for turbulent, compressible fluids, assuming a locally infinitely extended swept wing in a surface coordinate system. The function and efficiency of the method are illustrated by two test cases. Compared with integral methods the LISW method requires larger calculation times, but allows a simple exchange of turbulence models and a simpler adaptation to changed boundary conditions. ESA

**N90-16194\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA. Inst. fuer Entwurfsaerodynamik.

**CONVERGENCE SPEEDING UP IN THE CALCULATION OF THE VISCOUS FLOW ABOUT AN AIRFOIL [KONVERGENZBESCHLEUNIGUNG BEI DER BERECHNUNG DER REIBUNGSBEHAFTETEN UMSTROMUNG EINES TRAGFLUEGELS]**

R. RADESPIEL and C. ROSSOW (Deutsche Forschungs- und Versuchsanstalt fuer Luft- und Raumfahrt, Brunswick, Germany, F.R.) /in DGLR, Flows with Separation p 301-312 1988 In GERMAN

Avail: NTIS HC A17/MF A03 CSCL 20/4

A finite volume method to solve the three dimensional Navier-Stokes equations was developed. It is based on a cell-vertex scheme with central differences and explicit Runge-Kutta time steps. A good convergence for a stationary solution was obtained by the use of local time steps, implicit smoothing of the residues, a multigrid algorithm, and a carefully controlled artificial dissipative term. The method is illustrated by results for transonic profiles and airfoils. The method allows a routine solution of the Navier-Stokes equations. ESA

**N90-16196#** Dornier System G.m.b.H., Friedrichshafen (Germany, F.R.). Numerische Stroemungsmechanik.

**PERIODICALLY UNSTEADY EFFECTS ON PROFILES, INDUCED BY SEPARATION [DURCH ABLOESUNG INDUZIERT, PERIODISCH-INSTATIONAERE EFFEKTE AN PROFILEN]**

EDGAR A. GERTEISEN /in DGLR, Flows with Separation p 327-341 1988 In GERMAN

Avail: NTIS HC A17/MF A03

The possibilities of allowing larger time steps in time accurate methods were investigated, with a view to the application of Euler and Navier-Stokes methods for the analysis of nonlinear phenomena. Almost no gain was obtained for the time accurate multigrid formulation; the time step could be enhanced by maximum one order of magnitude. The fully implicit approximation of the Euler flux terms is a suitable means (through the stabilization of the algorithm) for an efficient time accurate flow calculation. ESA

**N90-16294\*#** Virginia Polytechnic Inst. and State Univ., Blacksburg. Dept. of Engineering Science and Mechanics.

**FATIGUE LIFE ESTIMATES FOR HELICOPTER LOADING SPECTRA**

A. K. KHOSROVANEH, N. E. DOWLING, A. P. BERENS, and J. P. GALLAGHER (Dayton Univ., OH.) Dec. 1989 108 p (Contract NAG1-822)

(NASA-CR-181941; NAS 1.26:181941) Avail: NTIS HC A06/MF A01 CSCL 20/11

Helicopter loading histories applied to notch metal samples

are used as examples, and their fatigue lives are calculated by using a simplified version of the local strain approach. This simplified method has the advantage that it requires knowing the loading history in only the reduced form of ranges and means and number of cycles from the rain-flow cycle counting method. The calculated lives compare favorably with test data. Author

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Includes geosciences (general); earth resources; energy production and conversion; environment pollution; geophysics; meteorology and climatology; and oceanography.

**A90-21386**

**WIND SHEAR DETECTION WITH PENCIL-BEAM RADARS**

M. W. MERRITT, D. KLINGLE-WILSON, and S. D. CAMPBELL (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 483-510. Research sponsored by FAA. refs

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The characteristics and operation of the Terminal Doppler Weather Radar (TDWR) system are described. The TDWR utilizes automatic computer algorithms to identify hazardous weather conditions such as wind shear caused by microbursts and gust fronts. The structure and formation of microbursts and gust fronts are discussed; diagrams of these occurrences are provided. The performance of the TDWR system is evaluated using data obtained at Stapleton Airport in Denver during the summer of 1988. The data reveal that the wind shear and wind-shift algorithms perform well and are beneficial to the safety and efficiency of terminal operations. I.F.

**A90-22445#**

**NEW HIGH-SPEED AIR TRANSPORT SYSTEM AND STRATOSPHERIC POLLUTION**

A. GIRARD (ONERA, Chatillon-sous-Bagneux, France) and D. CARIOLLE (Centre National de la Recherche Meteorologique, Toulouse, France) (European Symposium on Future Supersonic Hypersonic Transportation Systems, Strasbourg, France, Nov. 6-8, 1989) ONERA, TP no. 1989-202, 1989, 8 p. refs (ONERA, TP NO. 1989-202)

Impressive progress has been made in the characterization of the chemical, dynamical, and transport processes of the stratosphere in the 20 years since the controversy over the Concorde SST's effects on atmospheric chemistry began. In addition, vastly expanded computational capabilities have become available for atmospheric chemical processes' three-dimensional modeling. Nevertheless, any further studies to be conducted on these questions will have to establish much more realistic SST fleet-operation scenarios than heretofore; the strong nonlinearity of many photochemical processes renders the extrapolation of partial results extremely hazardous. O.C.

**A90-22688**

**THE INFLUENCE OF WEATHER ON FLIGHT OPERATIONS AT THE ATLANTA HARTSFIELD INTERNATIONAL AIRPORT**

PETER J. ROBINSON (North Carolina, University, Chapel Hill) Weather and Forecasting (ISSN 0882-8156), vol. 4, Dec. 1989, p. 461-468. Research supported by the University of North Carolina. refs

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The impact of various types of weather on aircraft operations for one airline for three years at Atlanta Hartsfield International Airport is investigated. Impacts are expressed as delays defined in terms of the difference between the actual flight time and that projected by the air traffic control system assuming an accurate weather forecast. The impacts of weather events were measured as the difference between these delays in clear conditions and in

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various types of inclement weather. Fog and thunderstorms create delays in various phases of each flight. Delays associated with three snowstorms were also investigated. Early morning storms, even when forecast relatively late, have a rather small impact since few operations are airborne. Late-day storms, even if forecast early, have a much greater impact, since operations are well under way. Forecasts, in the case of snow events, are most valuable in assisting the airlines in canceling flights and rescheduling them once the storm is past. Author

**A90-22689#**

### **ENVIRONMENTAL CONDITIONS ASSOCIATED WITH THE DALLAS MICROBURST STORM DETERMINED FROM SATELLITE SOUNDINGS**

GARY ELLROD (NOAA, Satellite Applications Laboratory, Washington, DC) Weather and Forecasting (ISSN 0882-8156), vol. 4, Dec. 1989, p. 469-484. refs

The thermodynamic structure of the troposphere in the vicinity of the microburst at Dallas-Ft. Worth Airport (DFW), Texas on August 2, 1985 is described. The analysis was based principally on a set of vertical soundings from the VISSR Atmospheric Sounder (VAS) onboard the GOES, valid about 1 h before the occurrence of peak surface winds. Convection in the DFW area developed in a gradient of stability on the west side of a tongue of low lifted index and high precipitable water. The lapse rates in 850-700 mb layer were large (8-9 C/km). Vertical profiles of VAS data showed that DFW was in transition zone in which conditions became drier at all levels and slightly warmer near 500 mb to the south and southwest. The midlevel warming reduced the buoyant energy available above cloud base, thus acting as a capping mechanism for the unstable, northward-moving low-level air. The potential instability was released in the vicinity of DFW by low-level convergence, caused in part by an outflow boundary from earlier convection. The storm had characteristics of both the wet and dry types of microbursts based on current models. There was a large decrease with height in total static energy (inferred from equivalent potential temperatures) from the surface to 700 mb, resulting in a source of potentially cool air fairly close to the surface. Author

**A90-23255\*#** Computer Sciences Corp., Huntsville, AL.

### **ANALYSIS OF EXTREME WIND SHEAR**

STANLEY I. ADELFGANG and ORVEL E. SMITH (Computer Sciences Corp., Huntsville, AL) Journal of Spacecraft and Rockets (ISSN 0022-4650), vol. 27, Jan.-Feb. 1990, p. 21-24. Research supported by NASA. Previously cited in issue 09, p. 1384, Accession no. A89-25549. Copyright

**A90-23286\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **MULTIPLE VORTEX RING MODEL OF THE DFW MICROBURST**

THOMAS A. SCHULTZ (NASA, Ames Research Center, Moffett Field, CA) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 163-168. Previously cited in issue 07, p. 1060, Accession no. A88-22511. refs

**A90-23632**

### **WIND SHEAR AND HYPERBOLIC DISTRIBUTIONS**

O. E. BARNDORFF-NIELSEN, J. L. JENSEN, and M. SORENSEN (Aarhus Universitet, Denmark) Boundary-Layer Meteorology (ISSN 0006-8314), vol. 49, no. 4, Dec. 1989, p. 417-431. refs Copyright

Results are presented from an analysis of the data set on wind shear distributions described by Woodfield and Woods (1983). The wind shear data include 24 frequency distributions of changes in headwind speed experienced by aircraft during landing phase. The data set is analyzed by means of hyperbolic distribution. It is shown that the hyperbolic distributions produce a well-fitting and parsimonious reduction of the data. Consideration is given to the use of the resulting model for flight control, risk evaluation, and flight simulation. R.B.

**N90-15043#** Office National d'Etudes et de Recherches Aérospatiales, Paris (France).

### **DESCRIPTION OF ATMOSPHERIC TURBULENCE**

#### **[DESCRIPTION DE LA TURBULENCE ATMOSPHERIQUE]**

PIERRE-MARIE HUTIN In AGARD, Flight in Adverse Environmental Conditions 14 p Sep. 1989 In FRENCH Previously announced in IAA as A89-48750

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Over one million hours of aircraft flight test data for loading factors in excess of 0.5 g were analyzed using three different methods in order to model coherent atmospheric turbulence. The Houbolt method (using a rigid body with two degrees of freedom for the aircraft flight mechanics) is found to provide a better description of the atmosphere than either the Pratt method (in which turbulence values are obtained from the vertical acceleration of the aircraft) or the Hall method (using only a single degree of freedom for the aircraft motion). The Houbolt method is improved by a calibration using exact calculations for a small number of different aircraft configurations. IAA

**N90-15044#** Technische Univ., Brunswick (Germany, F.R.). Inst. of Guidance and Control.

### **WIND SHEAR MODELS FOR AIRCRAFT HAZARD INVESTIGATION**

MANFRED SWOLINSKY In AGARD, Flight in Adverse Environmental Conditions 17 p Sep. 1989

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Wind shear hazard investigations, flight simulation for pilot training as well as design, development, and testing of flight control systems require suitable wind models. Based on flight test data, airline flight data and meteorological tower measurements, engineering models for dangerous wind shear situations were developed in the frame of different wind shear research projects. Derived from simplified fluid dynamic concepts the engineering models for downburst, frontal wind shear, and low level jet meet the requirements for real-time flight simulation. The comparison of the wind models with measured wind data show good accordance. For the analyses of simulated landing approaches in wind shear conditions a hazard definition is given by means of aircraft energy height deficit, respectively the required energy supply for landing approach on nominal glide slope and constant air speed. Author

**N90-15045\*#** National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

### **ANALYSIS OF SEVERE ATMOSPHERIC DISTURBANCES FROM AIRLINE FLIGHT RECORDS**

R. C. WINGROVE, R. E. BACH, JR., and T. A. SCHULTZ In AGARD, Flight in Adverse Environmental Conditions 7 p Sep. 1989 Previously announced as N89-25977

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Advanced methods were developed to determine time varying winds and turbulence from digital flight data recorders carried aboard modern airliners. Analysis of several cases involving severe clear air turbulence encounters at cruise altitudes has shown that the aircraft encountered vortex arrays generated by destabilized wind shear layers above mountains or thunderstorms. A model was developed to identify the strength, size, and spacing of vortex arrays. This model is used to study the effects of severe wind hazards on operational safety for different types of aircraft. It is demonstrated that small remotely piloted vehicles and executive aircraft exhibit more violent behavior than do large airliners during encounters with high-altitude vortices. Analysis of digital flight data from the accident at Dallas/Ft. Worth in 1985 indicates that the aircraft encountered a microburst with rapidly changing winds embedded in a strong outflow near the ground. A multiple-vortex-ring model was developed to represent the



microburst wind pattern. This model can be used in flight simulators to better understand the control problems in severe microburst encounters. Author

**N90-15046#** Aerodata Flugmesstechnik G.m.b.H., Brunswick (Germany, F.R.).

# **SYSTEMS FOR AIRBORNE WIND AND TURBULENCE MEASUREMENT**

PETER VOERSMANN /in AGARD, Flight in Adverse Environmental Conditions 12 p Sep. 1989

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For many years aircraft were equipped for research in wind and turbulence measurements. Very often the system installation consisted of sensors and recording hardware which was spread all over the aircraft. A modern system solution, where all components are integrated in an external pod for aircraft and helicopter applications is described. After a brief description of the principles for airborne wind measurements, advantages and disadvantages for different system solutions will be discussed. The presented pod solution includes a software and hardware concept, which allows to determine all three components of the wind vector in real time on-board the aircraft. Flight test results are presented, which demonstrate the achievable accuracies for the horizontal and especially the vertical wind component. This includes the effects of dynamic aircraft maneuvers. Finally an outlook is given, what kind of precision can be achieved in the future, when satellite navigation systems will be available on a 24 hour basis. Author

**N90-15049#** Royal Aircraft Establishment, Bedford (England).

# **CLASSIFICATION OF WINDSHEAR SEVERITY**

A. A. WOODFIELD /in AGARD, Flight in Adverse Environmental Conditions 13 p Sep. 1989

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A simplified model of aircraft and pilot response to wind shear is used to identify the potential height loss during wind shear encounters. This potential height loss is directly related to the possibility of unscheduled ground contact and is proposed as a primary indicator of wind shear severity. Key factors of wind shear strength and aircraft performance which influence the potential height loss are identified using this simple model. This helps to provide a better understanding of the complex interactions between the pilot/aircraft and the wind shear. Various practical severity factors are examined in relation to both the potential height loss and the probability of encountering various shears. It is shown that severity factors based on pseudo-energy-rate have fundamental problems in resolving the conflict between false alarms and providing timely information to a pilot when used with current sensors on aircraft or sensors that scan and probe (such as Doppler radar or laser). An improved severity factor based on the potential height loss analysis is shown to have a low risk of false or missed alarms, and appropriate threshold values are easily identified for all aircraft types. This improved severity factor requires probe and scan sensors. Author

**N90-15052#** National Aeronautical Establishment, Ottawa (Ontario). Flight Research Lab.

# **ADVERSE WEATHER OPERATIONS DURING THE CANADIAN ATLANTIC STORMS PROGRAM**

J. I. MACPHERSON and G. A. ISAAC (Atmospheric Environment Service, Downsview, Ontario) /in AGARD, Flight in Adverse Environmental Conditions 13 p Sep. 1989

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For cooperative research programs with the Atmospheric Environment Service of Canada, the NRC Twin Otter Atmospheric Research Aircraft was instrumented to measure the motion and thermal structure of the atmosphere and the microphysics of cloud and precipitation. In 1986 the aircraft was flown in the Canadian

Atlantic Storms Program to investigate large east-coast storms that typically account for the bulk of the winter-time precipitation in the Maritime provinces, and cause havoc for airborne and surface transportation. A variety of adverse flight conditions were experienced including heavy snow contributing to limited IFR alternates, airframe icing, wind shear and crosswinds on landing. Examples are presented of these incidents analyzed from both a flight research and meteorological perspective using aircraft recorded data. For this project, additional specially-designed deicing boots were installed on the Twin Otter's vertical tail and the wing and landing gear struts. The performance of the enhanced aircraft deicing system will be discussed using data from three deicing encounters. Author

**N90-15519#** Midwest Research Inst., Golden, CO. Solar Energy Research Inst.

# **INCLUSION OF NONLINEAR AERODYNAMICS IN THE FLAP CODE**

TIM L. WEBER Nov. 1989 8 p Presented at the 9th ASME Wind Energy Symposium, New Orleans, LA, 14-17 Jan. 1990

(Contract DE-AC02-83CH-10093)

(DE89-009507; SERI/TP-257-3558; CONF-900136-5) Avail: NTIS HC A02/MF A01

Horizontal axis wind turbines usually operate with significant portions of the blade in deep stall. This contradicts the assumption in the FLAP code that a linear relation exists between the angle of attack and the lift coefficient. The objective is to determine the importance of nonlinear aerodynamics in the prediction of loads. The FLAP code was modified to include the nonlinear relationships between the lift and drag coefficients with the angle of attack. The modification affects the calculation of the induced velocities and the aerodynamic loads. This requires an iterative procedure to determine the induced velocities instead of a closed form solution. A more advanced tower interference model was also added that accounts for both upwind and downwind tower effects. DOE

**N90-15566#** Oklahoma Univ., Norman. Cooperative Inst. for Mesoscale Meteorological Studies.

# **TURBULENCE SPECTRAL WIDTHS VIEW ANGLE**

## **INDEPENDENCE AS OBSERVED BY DOPPLER RADAR Final Report**

J. T. LEE and K. THOMAS Oct. 1989 56 p

(Contract DTFA01-80-Y-10524)

(DOT/FAA/SA-89/2) Avail: NTIS HC A04/MF A01

As air traffic density increases, effective use of airspace must include consideration of weather. Accurate identification of turbulent volumes is of paramount importance to flight safety. The advent of Doppler radar has made it possible to observe wind motion in convective clouds. Over a number of years, research has led to the spectral width (standard deviation) of the Doppler velocity measurements as an indicator of turbulence. The hypotheses that turbulence is essentially isotropic in convective systems, and therefore, observations of turbulence are independent of viewing angle, is addressed. Radar observations made during the months of April, May, and June in 1980 to 1985 were scanned to locate storms amenable to analysis. A number of cases are presented in which a dual-Doppler network provided the essential data. Each case is in a different quadrant with respect to the Norman Doppler. Forty-four horizontal planes were studied from six different storms. The results of four of these storms included range from near surface to 7 km. At these altitudes the maximum spectral width was 12 ms(exp -1). For these cases, involving nearly 30,000 data points, 70 percent of the spectral width observations from CIM and NRO were within 1 ms(exp -1) or less. These results indicate that the use of Doppler radar to detect turbulent regions within thunderstorms has a high probability of success, and the turbulent regions can be detected independent of the direction from which they are viewed. Author

## MATHEMATICAL AND COMPUTER SCIENCES

Includes mathematical and computer sciences (general); computer operations and hardware; computer programming and software; computer systems; cybernetics; numerical analysis; statistics and probability; systems analysis; and theoretical mathematics.

A90-20380

**BEYOND THE LIMITS - FLIGHT ENTERS THE COMPUTER AGE**

PAUL E. CERUZZI (National Air and Space Museum, Washington, DC) Cambridge, MA, MIT Press, 1989, 276 p. refs  
Copyright

The application of computer technology to the design of aircraft and spacecraft in the U.S. is discussed in a historical overview. Chapters are devoted to the evolution of computers and aerospace; pioneering efforts at Northrop Aviation; logistics and the Rand Corporation; missile tracking and the search for real-time performance; the Whirlwind computer; Minuteman, Apollo, and the chip; advances in design and production; advances in simulation, testing, and control; software; and the role of computers in the loss of the Space Shuttle Challenger. Extensive diagrams, drawings, and photographs are provided. T.K.

A90-20557

**DESIGN OF A HELICOPTER OUTPUT FEEDBACK CONTROL LAW USING MODAL AND STRUCTURED-ROBUSTNESS TECHNIQUES**

P. APKARIAN, C. CHAMPETIER, and J. F. MAGNI (ONERA, Centre d'Etudes et de Recherches de Toulouse, France) International Journal of Control (ISSN 0020-7179), vol. 50, Oct. 1989, p. 1195-1215. refs  
Copyright

A procedure is described for designing output-feedback control laws based on a mixture of modal and frequency domain approaches. In the first step of this procedure, a state-feedback control law is synthesized. The modal approaches are used for dealing with dynamic performances while the robustness is optimized by using frequency domain criteria. The robustness measure adopted here is based on structured singular values in such a way that not only the stability but also the damping ratio are robust against uncertainties. In the second step, a minimal-order observer output-feedback control law, defined in an eigenstructure setting, is performed in such a way that both modal and robustness properties are recovered. The robustness of the technique is illustrated using a realistic helicopter problem. Author

A90-21385

**MODELING OF AIR-TO-AIR VISUAL ACQUISITION**

J. W. ANDREWS (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 475-482. refs  
Copyright

The development of the mathematical model for air-to-air visual acquisition is discussed. The model represents the visual acquisition process as a nonhomogeneous Poisson process. Data for unalerted-search and alerted-search tests are presented and compared. It is observed that 1 sec of search with the traffic alert and collision avoidance system advisory is as effective as 8 sec of search with no alert. I.F.

A90-21389

**APPLYING ARTIFICIAL INTELLIGENCE TECHNIQUES TO AIR TRAFFIC CONTROL AUTOMATION**

D. A. SPENCER (MIT, Lexington, MA) The Lincoln Laboratory Journal (ISSN 0896-4130), vol. 2, Fall 1989, p. 537-554. Research sponsored by FAA. refs  
Copyright

A computer program that automates basic ATC planning and decision-making functions is described. The functions the automated system handles are: (1) coordinating with other sectors,

(2) navigating aircraft, (3) issuing altitude clearance, and (4) maintaining aircraft separation. Difficulties associated with automating ATC and the limitations of an automated system are discussed. The automated controller is tested using different flight-strip data. It is noted that this system is capable of performing basic ATC and conflict-resolution tasks. An example of the system's applicability is provided. I.F.

A90-22199\*# National Aeronautics and Space Administration. Ames Research Center, Moffett Field, CA.

**MULTI-PROCESSING ON SUPERCOMPUTERS FOR COMPUTATIONAL AERODYNAMICS**

MAURICE YARROW (NASA, Ames Research Center; Sterling Software, Moffett Field, CA) and UNMEEL B. MEHTA (NASA, Ames Research Center, Moffett Field, CA) AIAA, Aerospace Sciences Meeting, 28th, Reno, NV, Jan. 8-11, 1990. 24 p. refs  
(AIAA PAPER 90-0337) Copyright

The MIMD concept is applied, through multitasking, with relatively minor modifications to an existing code for a single processor. This approach maps the available memory to multiple processors, exploiting the C-FORTRAN-Unix interface. An existing single processor algorithm is mapped without the need for developing a new algorithm. The procedure of designing a code utilizing this approach is automated with the Unix stream editor. A Multiple Processor Multiple Grid (MPMG) code is developed as a demonstration of this approach. This code solves the three-dimensional, Reynolds-averaged, thin-layer and slender-layer Navier-Stokes equations with an implicit, approximately factored and diagonalized method. This solver is applied to a generic, oblique-wing aircraft problem on a four-processor computer using one process for data management and nonparallel computations and three processes for pseudotime advance on three different grid systems. C.D.

A90-22435

**EQUIPMENT PROCUREMENT - EH101 HELICOPTER**

SCOTT D. ROY (Westland Helicopters, Ltd., Yeovil, England) IN: Systems analysis in aerospace; Proceedings of the Symposium, London, England, May 11, 12, 1988. London, Royal Aeronautical Society, 1988, p. 28-33.  
Copyright

An account is given of the approach taken in the application of systems-analysis methods to the design of the EH101 military helicopter, as well as of the character of the mathematical models and simulations developed explicitly for application in the EH101 program. The analysis proceeded via (1) the definition of objectives, (2) the formulation of measures of effectiveness, (3) the evaluation of alternative design concepts, and (4) specification and implementation. O.C.

A90-23241#

**A FIBEROPTIC LAN FOR AIRCRAFT AND OTHER APPLICATIONS**

L. C. MANOHARAN and S. MUTHUVEL (National Aeronautical Laboratory, Bangalore, India) Institution of Engineers (India), Journal, Aerospace Engineering Division (ISSN 0257-3423), vol. 69, Sept. 1988-Mar. 1989, p. 10-12. refs

A fiberoptic LAN master-slave configuration is proposed for digital data transmission on aircraft. The LAN is acceptable to the MIL-STD-1773 fiberoptic data bus. The maximum bandwidth of incoming data at any substation or remote terminal is 200 Hz. Consideration is given to the operation of the LAN and the process of eliminating a faulty substation or subsystem, or switching over to a redundant bus. Also, applications of the network for ground based systems such as missile launching are discussed. R.B.

A90-23372

**AEROSPACE COORDINATE SYSTEMS AND TRANSFORMATIONS**

G. MINKLER and J. MINKLER Baltimore, MD, Magellan Book Co., 1990, 317 p. refs  
Copyright

A detailed description is given of the 10 most commonly used

aerospace coordinate systems, including the important wander azimuth navigational coordinate system. Expressions for both point and vector transformations are developed for transformations between each of the coordinate systems. A detailed discussion of quaternions and their use for vector and point transformations is presented. FORTRAN code for point transformations between selected coordinate systems is provided, and an introductory level review of the mathematical foundations of coordinate systems and transformations is given. C.D.

A90-23681

# **COMPUTER INTEGRATED QUALITY ASSURANCE FOR ROBOTIC WORKCELLS IN AEROSPACE MANUFACTURING**

KENNETH E. WRIGHT and BRANKO SARH (Rohr Industries, Inc., Riverside, CA) Society of Manufacturing Engineers, Robots in Aerospace Manufacturing Conference, Irvine, CA, Feb. 20-23, 1989. 22 p.

(SME PAPER MS89-152) Copyright

A computer-integrated automated robotic workcell is being implemented in an aerospace structural assembly environment to enhance efficiency and flexibility, pursuant to the USAF's interests in the development of automated assembly techniques. Attention is given to this system's Computer-Integrated Quality Assurance software package, which encompasses and integrates automation, data-handling, expert system, and enhanced quality-assurance procedures for the monitoring, control, and inspection of the structural assembly process. O.C.

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## PHYSICS

Includes physics (general); acoustics; atomic and molecular physics; nuclear and high-energy physics; optics; plasma physics; solid-state physics; and thermodynamics and statistical physics.

A90-21474

# **TECHNICAL-SCIENTIFIC POSSIBILITIES FOR HELICOPTER NOISE RESEARCH IN THE GERMAN-DUTCH WIND TUNNEL [TECHNISCH-WISSENSCHAFTLICHE MOEGELICHKEITEN FUER DIE HUBSCHRAUBER-LAERMFORSCHUNG IM DEUTSCH-NIEDERLAENDISCHEN WINDKANAL]**

HANNO HELLER, WOLF SPLETTSTOESSER, and KLAUS-J. SCHULTZ (DLR, Institut fuer Entwurfsaerodynamik, Brunswick, Federal Republic of Germany) DLR-Nachrichten (ISSN 0937-0420), Nov. 1989, p. 74-78. In German.

Copyright

The results of helicopter noise research performed in the German-Dutch wind tunnel are reviewed. The findings concerning the origin and propagation of impulsive noise are described along with the methods used to measure the noise. Improved test beds for the main rotor and tail rotors are examined. C.D.

A90-23288#

# **RANDOM RESPONSE AND NOISE TRANSMISSION OF DISCRETELY STIFFENED COMPOSITE PANELS**

CONSTANTINOS S. LYRINTZIS (San Diego State University, CA) and RIMAS VAICAITIS (Columbia University, New York) (Structures, Structural Dynamics and Materials Conference, 29th, Williamsburg, VA, Apr. 18-20, 1988, Technical Papers, Part 1, p. 138-146) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 176-184. Research supported by the San Diego State University Foundation. Previously cited in issue 12, p. 1944, Accession no. A88-32192. refs

Copyright

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## SOCIAL SCIENCES

Includes social sciences (general); administration and management; documentation and information science; economics and cost analysis; law and political science; and urban technology and transportation.

**A90-23282\*#** National Aeronautics and Space Administration. Langley Research Center, Hampton, VA.

# **MINIMIZING LIFE CYCLE COST FOR SUBSONIC COMMERCIAL AIRCRAFT**

VICKI S. JOHNSON (NASA, Langley Research Center, Hampton, VA) Journal of Aircraft (ISSN 0021-8669), vol. 27, Feb. 1990, p. 139-145. refs

Copyright

A methodology is presented which facilitates the identification of that aircraft design concept which will incur the lowest life-cycle costs (LCCs) while meeting mission requirements. The methodology consists of an LCC module whose constituent elements calculate the costs associated with R&D, testing, evaluation, and production, as well as direct and indirect operating costs, in conjunction with the 'Flight Optimization System' conceptual design/analysis code. Provision is made in the methodology for sensitivities to advanced technologies for the subsonic commercial aircraft in question, which are optimized with respect to minimum gross weight, fuel consumption, acquisition cost, and direct operating cost. O.C.

## 19

## GENERAL

A90-20604

# **GAS TURBINE COMBUSTION - A PERSONAL PERSPECTIVE**

R. O. WINDLEY (Aero and Industrial Technology, Ltd., Burnley, England) Institution of Mechanical Engineers, Proceedings, Part G - Journal of Aerospace Engineering (ISSN 0954-4100), vol. 203, no. G2, 1989, p. 79-96. refs

Copyright

A development history and current status evaluation is presented for gas turbine combustor design and technology. The service life of the early Whittle gas turbine engine's combustion chamber was only some tens of hours; that of a representative current combustor is 20,000-30,000 hours, thanks primarily to improvements in combustor materials' creep-resistance and their configurations' careful use of cooling airflow patterns. In particular, the historically continuous increase in gas turbine compression ratios have resulted in shorter, smaller-volume combustor designs. Attention is given to the development of combustor wall-cooling, fuel injection, superalloys and coatings, and reverse-flow aerodynamic pattern configurations. Prospective developments are forecast. O.C.

**A-1**

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AIAA Lighter-Than-Air Systems Technology Conference, 8th, Jacksonville, FL, Oct. 5-7, 1989, Technical Papers p 221 A90-20576

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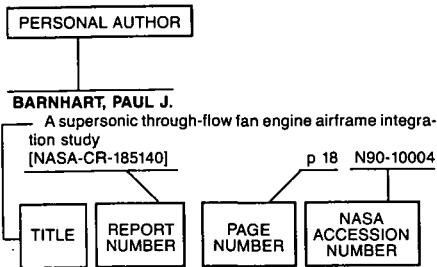
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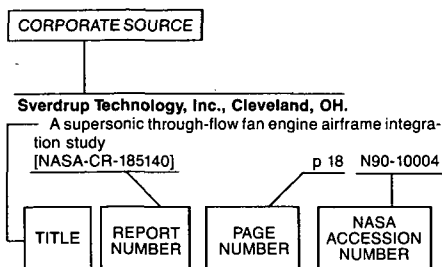
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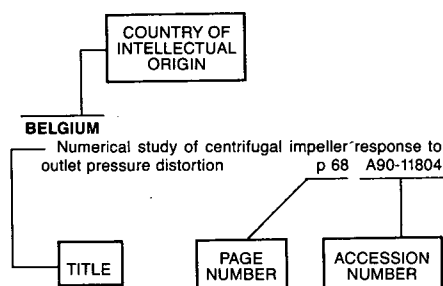
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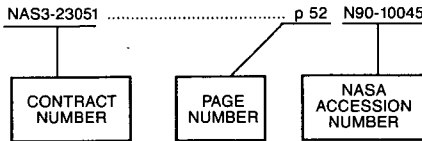
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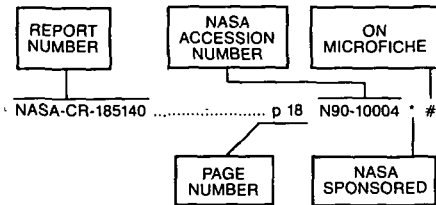
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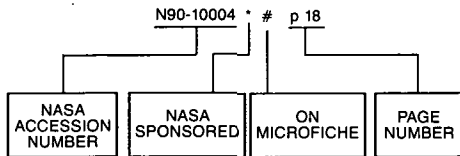
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May 1990

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4. Title and Subtitle Aeronautical Engineering A Continuing Bibliography (Supplement 252)				5. Report Date May 1990	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.	
9. Performing Organization Name and Address National Aeronautics and Space Administration Washington, DC 20546				10. Work Unit No.	
				11. Contract or Grant No.	
12. Sponsoring Agency Name and Address				13. Type of Report and Period Covered	
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15. Supplementary Notes					
16. Abstract This bibliography lists 425 reports, articles and other documents introduced into the NASA scientific and technical information system in April 1990.					
17. Key Words (Suggested by Authors(s)) Aeronautical Engineering Aeronautics Bibliographies				18. Distribution Statement Unclassified - Unlimited	
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		22. Price * A07/HC	
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## **WISCONSIN**

### **ST. HIST. SOC. OF WISCONSIN LIB.**

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Madison, WI 53706  
(608) 262-2781  
In cooperation with Univ. of Wisconsin-  
Madison, Memorial Library

### **MILWAUKEE PUBLIC LIBRARY**

Documents Division  
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Milwaukee, WI 53233  
(414) 278-3065

## **WYOMING**

### **WYOMING STATE LIBRARY**

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